76-3102

HOLLOWAY, Clifford Carlton, 1924-
USE OF RUMINANT ANIMALS IN REFUSE DISPOSAL
(A STUDY FOR PERTH, WESTERN AUSTRALIA).

The University of Oklahoma, Ph.D., 1975
Engineering, sanitary and municipal

Xerox University Microfilms, Ann Arbor, Michigan 48106

THE UNIVERSITY OF OKLAHOMA

GRADUATE COLLEGE

USE OF RUMINANT ANIMALS IN REFUSE DISPOSAL

(A STUDY FOR PERTH, WESTERN AUSTRALIA)

A DISSERTATION

SUBMITTED TO THE GRADUATE FACULTY

in partial fulfillment of the requirements for the

degree of

DOCTOR OF PHILOSOPHY

BY

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1975

USE OF RUMINANT ANIMALS IN REFUSE DISPOSAL

(A Study for Perth, Western Australia)

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USE OF RUMINANT ANIMALS IN REFUSE DISPOSAL

(A Study for Perth, Western Australia)

By

Clifford Carlton Holloway

Among the largest problems facing man today are food, energy, and the disposal of waste. These problems have a symbiotic relationship, i.e., to unilaterally solve one of them would soon jeopardize the function of the others; therefore, solutions will only be found where the production of food and energy along with disposing of the resulting waste becomes one system.

The purpose of this report is to study the problems of a particular community and present solutions for which a socially acceptable and economically viable technology exists at this time.

Problems of food, energy and the resulting waste could be ameliorated in Perth, Western Australia, by a combination of ruminant animals eating a portion of the refuse and the balance of the organics being decomposed in an anaerobic digestor along with feces and urine of the animals. Tests prove that adequate rations for ruminant animals can be formulated from the organic fraction of municipal waste and that their feces and urine would supply cellulose attacking enzymes to the anaerobic digestor. This could be of environmental significance; that is, less impact on the environment and an improved quality of life will result due to:

1. The organic fraction of municipal waste could be returned to the environment in a manner compatible with the ecosystems.

2. Animal food and fiber would be produced by the ruminant animals from material which is otherwise a source of pollution.

3. Energy would be produced in the form of CH_4 (methane) from the decomposition of the balance of the organic fraction.

4. Protein in the cells of the anaerobic microbes could be harvested for animal food.

5. The anaerobic digestor could provide supernatant for growing algae thereby providing further protein and making the waste water more suitable for returning to the ecosystem.

The technology exists for separating the organic fraction of municipal waste from the metals, glass, etc., so that the latter may be recycled or disposed of in a landfill. Also, the technology for anaerobic digestion of organic wastes and utilizing the resulting methane gas has existed for more than 50 years in the field of sanitary engineering.

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USE OF RUMINANT ANIMALS IN REFUSE DISPOSAL

(A STUDY FOR PERTH, WESTERN AUSTRALIA)

CHAPTER I

A. Introduction

Among the major problems facing man today are food, energy and the disposal of waste. These problems have a symbiotic relationship, i.e., to unilaterally solve one of them would soon jeopardize the function of the others. Therefore, solutions will be found only where the production of food and energy, along with the disposal of the resultant waste, becomes one system.

The responsibility for waste disposal is usually with the municipal government. The ultimate solutions to municipal refuse problems are closely connected with architecture, engineering, urban planning, marketing and patterns of consumption. These "ultimate solutions" will require social change in the form of modified life-styles and behavioral patterns. Therefore, because of their complexity, these "ultimate solutions" are perhaps in the distant future.

The purpose of this paper is to study the waste disposal problems of a particular community and present solutions for which a socially acceptable and economically viable technology exists at this time.

These problems of food, energy and the resultant waste could be ameliorated in Perth, Western Australia, by a combination of ruminant animals eating a portion of the refuse, and the remainder of the organics being decomposed in an anaerobic digestor, along with the feces and urine of the animals. Tests indicate that adequate rations for ruminant animals can be formulated from the organic fraction of municipal waste,[1, 27, 28] and that the feces and urine from the animals would supply cellulose decomposing and methane producing enzymes to the anaerobic digestor.[2] A system incorporating these features could be of environmental significance in that it could provide a means of municipal refuse management with less impact on the environment than those currently used. An improved quality of life would result, due to the following advantages:

1. The organic fraction of municipal waste could be returned to the environment in a manner compatible with the ecosystems.

2. Animal food and fiber would be produced by the ruminant animals from material which is otherwise a source of pollution.

3. Energy would be produced in the form of CH_4 (methane) from the fermentation of the balance of the organic fraction.

4. Protein in the cells of the anaerobic microbes could be harvested for animal food.[3]

5. The anaerobic digestor could provide supernatant nutrients for growing algae, thereby providing further protein and making the wastewater more suitable for returning to the ecosystem.[4, 15]

The technology exists for separating the organic fraction of municipal waste from the metals, glass, etc. so that the latter may be recycled or safely disposed of in a landfill or other means.[5, 6, 31] In addition, the technology for anaerobic digestion of organic wastes and utilizing the resulting methane gas has been applied by sanitary engineers for more than fifty years.[7, 13, 36]

Viability of Total Scheme

This scheme is economically valid because it operates as a total system and takes advantage of some situations that are unique to Western Australia.

Important factors are:

1. Moderate temperatures and abundant sunlight for algae growth.
2. High organic content of waste due to the lack of residential garbage grinders.
3. Price obtainable for natural gas (\$2.70 per 10^6 Btu's in Perth, Australia, compared to \$0.35 per 10^6 BTU in Oklahoma City, Oklahoma).
4. Rapid escalation in the prices of protein for animal food supplements. A combination of factors have caused shortages in animal feed protein supplements unparalleled in peacetime: failure of Peruvian fish harvest, reduction of cereal reserves throughout the world, and rapid population growth.

Basically the system processes municipal refuse by:

1. Mechanical and hydraulic separation of the refuse.

2. Animal ration formulation from a portion of the organic fraction of the waste.
3. Anaerobic decomposition of the animal feces and urine, along with the remaining organic fraction of the refuse.
4. Harvesting the cells (protein) of the anaerobic microbes.
5. Growing algae for harvest on the effluent from the reactor.

This system would then be environmentally desirable and socially acceptable, as well as economically feasible.

B. Definitions of Terms for Wastes

Due to the ambiguous use of such words as "garbage," it is necessary to set down exact definitions of terms. The American Public Works Association has arrived at the most widespread meanings of articles discarded by the community. These terms are included in Appendix A and are summarized in Table 1-1, pp. 7-8 for comparison with Western Australian terns used here.

The Public Health Department of Western Australia uses the following definitions in "A Report on Community Waste in Perth Metropolitan Region"[8]:

1. Commercial Waste

   Waste produced by shops and offices and consists largely of fibreboard containers, wooden crates, paper packaging, paper, cards, etc. Also includes waste from hotels, restaurants and hospitals.

2. Community Waste

The total solid waste generated by the community, including waste from industrial or trade premises.

3. Domestic Waste

All solid waste generated in private dwellings such as garbage, lawn clippings, ashes, packaging, waste from repair and redecorating, old clothing, old floor coverings, and old furnishings, and which are removed by a regular Local Authority service.

4. Demolition Waste

All waste from the construction or demolition of buildings or other structures.

5. Garbage

The animal and vegetable waste resulting from handling, preparation, cooking and serving of food. It is composed largely of putrescible, organic matter and includes a minimum of free liquids. The term "garbage" may also be applied to wet refuse and "pig swill."

6. Industrial Solid Waste

All solid waste from industrial processors such as manufacturing operations, factories, refineries, etc.

7. Industrial Liquid Waste

Originates from same sources as industrial solid waste but is liquid in nature. Some industrial liquid waste is highly toxic.

8. Liquid Waste

All liquid waste removed from grease traps or impermeable receptacles and includes the contents removed from septic tanks and all types of soak wells and sullage waste.

9. Mining Waste

Processed or unprocessed minerals generated in large quantities in the course of mining activities, ore processing, and extractive industries.

10. Municipal Refuse

All solid waste collected from private dwellings, commercial premises, trade and some industrial premises, by municipal collection services or private contractors acting on behalf of a municipal body.

11. Refuse

For the purposes of this report includes garbage, litter, ashes, street sweepings, lawn clippings, tree loppings, rubble and other builders' waste, unwanted household material, and derelict motor vehicles.

12. Sewage

The Health Act of 1911 - 73 defines sewage as "any kind of sewage, nightsoil, faecal matter or urine, and any waste composed wholly or in part of liquid."

TABLE 1-1

Classification of Refuse Materials

<table>
<tr><td rowspan="6">Refuse (Solid Wastes)</td><td>Garbage</td><td colspan="2">Wastes from the preparation, cooking, and serving of food. Market refuse, waste from the handling, storage, and sale of produce and meats.</td><td rowspan="4">From: households, institutions, and commercial concerns such as hotels, stores, restaurants, markets, etc.</td></tr>
<tr><td rowspan="2">Rubbish</td><td>Combustible (primarily organic)</td><td>Paper, cardboard, cartons
Wood, boxes, excelsior
Plastics
Rags, cloth, bedding
Leather, rubber
Grass, leaves, yard trimmings</td></tr>
<tr><td>Noncombustible (primarily inorganic)</td><td>Metals, tin cans, metal foils
Dirt
Stones, bricks, ceramics, crockery
Glass, bottles
Other mineral refuse</td></tr>
<tr><td>Ashes</td><td colspan="2">Residue from fires used for cooking and for heating buildings, cinders</td></tr>
<tr><td>Bulky Wastes</td><td colspan="2">Large auto parts, tires
Stoves, refrigerators, other large appliances
Furniture, large crates
Trees, branches, palm fronds, stumps, flotage</td><td rowspan="2">From: streets, sidewalks, alleys, vacant lots, etc.</td></tr>
<tr><td>Street Refuse</td><td colspan="2">Street sweepings, dirt
Leaves
Catch basin dirt
Contents of litter receptables</td></tr>
</table>

TABLE 1-1
(Continued)

Refuse (Solid Wastes)	Dead Animals	Small animals: cats, dogs, poultry, etc. Large animals: horses, cows, etc.	From: streets, sidewalks, alleys, vacant lots, etc.
	Abandoned Vehicles	Automobiles, trucks	
	Construction & Demolition Wastes	Lumber, roofing, and sheathing scraps Rubble, broken concrete, plaster, etc. Conduit, pipe, wire, insulation, etc.	
	Industrial Refuse	Solid wastes resulting from industrial processes and manufacturing operations such as: food-processing wastes, boiler house cinders, wood, plastic, and metal scraps and shavings, etc.	From: factories, power plants, etc.
	Special Wastes	Hazardous wastes: pathological wastes, explosives, radioactive materials Security wastes: confidential documents, negotiable papers, etc.	Households, hospitals, institutions, stores, industry, etc.
	Animal & Agricul. Wastes	Manures, crop residues	Farms, feed lots
	Sewage Treatment Residues	Coarse screenings, grit, septic tank sludge, dewatered sludge	Sewage treatment plants, etc.

C. Goals

The optimal approach to solving the solid waste problem must rely on a two-pronged thruse...environmental upgrading on the one hand, and recovery of materials and energy on the other. These thrusts depend upon one another and are mutually supportive...Recovery of materials and energy value of solid waste is not an option, but a necessity....We must stop all open dumping in this country. It is a cheap option -- too environmentally costly to be allowed to continued.[9]

One cannot deal adequately with wastes - the unreclaimed by-products of a complex industrial society - as though they existed outside the total structure of society. The environmental ills relating to wastes are by-products of ones life style--the way one thinks, or fails to think. They are wastes left over from the way one transports oneself and goods; the way one produces and utilizes energy; the way food is gorwn; roads are built, goods are produced, packaged and disposed of.

Refuse disposal is a socio-technical problem, i.e., it requires a working relationship between efficiency and desirability. The word "disposal" implies "to get rid of", which it is impossible to do; the refuse has to be sotred, reclaimed, or converted into other usable properties, or combinations of these.

Space to store our wastes is rapidly being depleted. For that reason reclamation and conversion are the remaining options. Therefore, the objective of this study is to produce a socially acceptable, economically feasible pollution-free system of reclaiming and converting municipal refuse. This system should recycle all material and energy values of the refuse back into the ecosystem.

Chapter II

STATE OF THE ART OF TREATING MUNICIPAL REFUSE

A. General

Until recently solid waste management practices relied upon disposing of waste in land fills or by incineration. Open dumping is still a widespread practice. However, the environmental hazards and the public nuisances of these policies are now widely recognized. Government agencies are adopting stricter standards regarding the disposal of solid waste. Communities and municipalities are confronted with these realities as well as pressures from environmentally concerned citizens who call for programs that are oriented towards recycling and reclamation.

B. Need for Resource Recovery

Because the world's natural resources are rapidly being depleted, increasing importance must be placed on the recovery for re - use of valuable resources from waste.

As stricter environmental controls make waste disposal more expensive, the economics of resource recovery becomes more attractive.

At the same time, the cost of energy is rising so that energy recovery from refuse has an economic as well as a social value. In the United States, the "Second Report to Congress, Resource Recovery and Source Reduction," (E.P.A. 1974) estimated that the energy potentially recoverable from post-consumer residential and commercial waste could supply roughly 1% of the nation's current energy demands, about 7% of the iron, 8% of the aluminum, 20% of the tin, and 14% of the paper consumed annually in the U.S.A.

Resource recovery has less impact on the environment than processing virgin material. "When the two production systems are compared -- one using virgin materials and the other, secondary materials -- the system using waste causes less air and water pollution, generates less solid waste, and consumes less energy."[9] The technology for refuse separation and recovery is well established. There are many plants in North America and Europe separating municipal refuse into its various components. Other plants are "digesting" organic waste, then utilizing the resultant methane.[10] Growing and harvesting algae is widespread.[41] In India animal manure has been digested and the methane used for more than twenty years.[11] Plants for digesting farm waste and utilizing the resultant methane were built in France shortly after World War II. However, no <u>one</u> plant is known to incorporate the specific combination of processes as is proposed here. The proposed plant depends on efficient anaerobic digestion. Excellent descriptions of this oxygen-devoid process appear in the literature.[12]

C. Technology for Treating Municipal Refuse

1. Historical and General

Dr. Steve Klein of the University of California has reported that as early as 1885 in Southampton, England, organic portions of refuse were combined with sewage in anaerobic digestion simply to prove they could be combined.[13] Early in this century, sewage treatment plants in Levenon, Pennsylvania, and Richmond, Indiana, were combining garbage with sewage. The concept of anaerobic digestion of the organic fraction of municipal refuse is clearly not new, but scientific data on the process was not available until this decade.

The earliest scientific experiments on the anaerobic decomposition of muncipal refuse were conducted by Dr. Steve Klein. In his 1967-68 experiments Dr. Klein pulverized the organic fraction of municipal waste and added it to sewage. This mixture was introduced into an anaerobic reactor and held at a temperature of 27-32^{o}, thereby producing 13 cubic feet of methane for every pound of raw material introduced. Since that time anaerobic digestion has been tested and proven to be an effective means of treatment of certain fractions of municipal solid waste.

One problem encountered in decomposing refuse in a reactor is to maintain an optimum carbon-nitrogen ratio. Ideally, this ratio should be no more than one part nitrogen to thirty parts carbon. Because refuse is very carbonaceous (approximately 80 parts carbon to one part nitrogen) it is necessary to add nitrogen for cell growth. Most processes use sewage sludge for this purpose, since it has a comparatively high nitrogen and other nutrient content. However, the addition of sewage sludge introduces all the pathogens inherent in it and is of considerable concern to the health authorities. The presence of these pathogens, in addition to aesthetic considerations, severely limits the uses of the by-products of this process. The feces of ruminant animals have a desirable nutrient content and could considerably reduce the above objections.

The ability and desirability of using animals for disposing of refuse has been known for centuries. Prior to this decade it was common for a household to have chickens eat table scraps, and dogs and cats subsisted on a similar diet. Goats' liking for old newspapers has been noted by farmers. The nutritional value of the organic fraction of municipal refuse is common knowledge. The refuse (swill) from restaurants, hotels, etc., has frequently been fed to swine. This was a recognized industry in North America more than one hundred years ago. A typical example is Worcester, Massachusetts (population then about 175,000):

> Since 1872 some portions of the city garbage have been taken to the Home Farm and fed to hogs. The Superintendent sent a wagon into the city to collect enough garbage to feed them. The work has developed with the growth of the city, and in 1918, about 70% of the garbage of Worcester was taken to the Home Farm, where there were from 2000 to 3000 hogs. A special so-called scavenging department has now been organized to handle this work. The garbage not collected by this department is taken by private collectors, and is also largely fed to hogs.[14]

The present objections to this practice in Perth are not based on nutrition, but on exotic diseases which might be introduced through imported foods. The trichinosis infection of swine in America is attributed to feeding swill to swine. Even though nutritional qualities have been long recognized, there is little scientific data available on the nutritional value of the organic fraction of municipal waste.

2. Ruminant Animals: Similarity of Rumen and Anaerobic Reactor.

Common rumen animals include cows, sheep, goats, buffalo, and camels. Dogs, cats, and chickens are non-rumens and therefore cannot utilize cellulose for energy.

In ruminants, a major part of the digestion process takes place by bacterial action and its end product includes a number of molecules less complex than the end product of digestion in animals with a more simple digestive tract.

Synthesis takes place in the rumen, because organisms grow, reproduce, and store polysaccharides and other compounds there. The high constant temperatures (39° C) and the anaerobic nature of the rumen are also important factors. Food entering the rumen is mixed with the microbial populations and remains there for about nine hours on the average. During this time, cellullytic bacteria and protozoa hydrolised cellulose to the disaccharide cellobiose and the monosaccharide glucose. These sugars then undergo a microbial fermentation with the production of volatile acids-primarily acetic, propionic and butyricand the gases carbon dioxide and methane. The volatile acids pass through the rumen wall into the blood stream and are oxidized by the animals as its main source of energy. In addition to their digestive functions, the rumen micro-organisms synthesize amino acids and vitamins that are the main source of these essential nutrients for the animal. The rumen contents, after fermentation, consist of many microbial cells plus partially digested plant material which passes into the stomach and gastro-intestinal tract of the animal, where they undergo digestive processes similar to those of other animals. Microbial cells formed in the rumen and digested in the gastro-intestinal tract are the main source of protein and vitamins for the animal. However, the feces and urine of the rumen animal continue to contain a high percentage of microbial cells.[2]

With regard to the actual amount of microbial cells found in feces and urine, tests by I. L. Willich showed that "the orders of magnitude of the microbial counts in the manure suspensions were: total counts, 10^8; anaerobes, 10^5 to 10^6; Escherichia coli, 10^5; enterococci, 10^4 to 10^6; and total fungi, 10^3 to 10^5 per ml of manure suspension."[2]

"The presence of methane-producing bacteria has been well established in cattle manure. Special microbial techniques are required to enumerate the rumen bacteria due to the anaerobic environment in the rumen and the varied metabolic characteristics of these micro-organisms.

It suffices to say that the microbial population in animal manure is more than adequate to bring about the chemical transformations which will occur when the manure is mixed with water."[2]

Professor R. E. McKinney[2] reported that when manure is mixed with water, microbial activity is very rapid. The oxygen is removed so quickly that it has no significant effect on the anaerobic bacteria that were growing in the manure prior to its discharge from the animal.

The microflora in the rumen is basically the same as that in an anaerobic reactor; they both break the cellulose molecule down into more usable carbohydrates. However, by increasing the detention time in an anaerobic reactor, it can be made to decompose particles which are too resistant for the nine hour detention time in the rumen. For this reason, it follows that the organic fraction of municipal waste which is unsuitable for digestion by the ruminant animal could be decomposed in an anaerobic reactor, along with the feces and urine of the animals. It is obvious that it is desirable for municipal waste to be separated into its organic and inorganic fractions before it is fed to animals or introduced into an anaerobic reactor.

D. Existing Resource Recovery Plants in the U.S.A.[16]

There are numerous plants in the United States which separate municipal refuse into its various fractions. The following is a list compiled by the E.P.A.

Types of resource recovery projects being pursued by communities:

Strict Materials Recovery

Franklin, Ohio

Lowell, Massachusetts

New Orleans, Louisiana

Combustion of Refuse to Produce Steam for Off-Site Use

Akron, Ohio

Albany, New York

Baltimore, Maryland

Braintree, Massachusetts

Cleveland, Ohio

Nashville, Tennessee

Saugus, Massachusetts

Recovery of Energy Through Use of Prepared Solid Waste as a Fuel In A Utility Type Boiler

Ames, Iowa

Brockton, Massachusetts

Bridgeport, Connecticut

Chicago, Illinois

Hackensack Meadowlands, New Jersey

Hempstead, New York

Honolulu, Hawaii

Housatonic Valley, Connecticut

Lane Company, Oregon

Los Angeles, California

Madison, Wisconsin

Memphis, Tennessee

Milwaukee, Wisconsin

Monroe Company, New York

Montgomery Company, Maryland

Montgomery Company, Ohio

New Britain, Connecticut

Palmer Township, Pennsylvania

St. Louis, Missouri

Washington, D.C.

Wilmington, Delaware

Bioconversion of Solid Waste to Produce Methane

Los Angeles, California

Tuscon, Arizona

Conversion of Solid Waste to Gas or Oil Using Pyrolysis

Baltimore, Maryland

Denver, Colorado

Knoxville, Tennessee

Minneapolis, Minnesota

Mt. Vernon, New York

San Diego County, California

Seattle, Washington

South Charleston, West Virginia

Westchester County, New York

Anaerobic Digestor

Although there are only two plants listed as using bioconversion of solid waste to produce methane, there are thousands of communities that use anaerobic digestors for sewage disposal. It is obvious that there exists, in essence, technology suitable for complete recycling of municipal refuse. Ft. Lauderdale, Florida, is approaching this goal.[5] Two problems facing most urban areas became especially critical in Ft. Lauderdale. First, emission standards for incinerators were becoming increasingly hard to meet at a reasonable cost. Second, the traditional landfill acreage (sanitary or otherwise) was either depleted, or in some areas, could not be employed at all. To dispose of refuse by an ecologically and economically sound recycling method and by the implementation of current technology, Ft. Lauderdale systematically sought alternative solutions to replace incineration.

After a detailed review, Ft. Lauderdale has contracted with a private firm to construct and operate a 600 ton-per-day plant on city property capable of modular expansion to 1,000 tons per day. The city guaranteed a 200-ton, $1,000 per day minimum payment with provision for adjusting rates to reflect increased costs.

The plant operates as follows. After the waste passes through several 200-ton shredders for volume and size reduction, magnetic separators are used to remove ferrous metals for direct sale. Automatic conveyors transport the remaining materials through hot air dryers to reduce moisture content to a consistent level. High-speed centrifugal and air reduction equipment (developed for mining and agricultural purposes) separates the fibrous materials from the pulverized glass, light metals, and grit. The mixed fibrous materials are then pathogenically decontaminated, and chemical treatments are utilized to improve processing characteristics of the fiber.

The resulting fiber from this process, approximately 25% by weight, has a greyish, raw cotton-like appearance, which consists of about half long-fiber premium kraft, approximately equivalent to that obtained from hardwood kraft and hardwood sulfite pulps. The fiber is baled automatically and is available for immediate shipment to either wet or dry conversion plants as a commodity fiber raw material in blending and combining cellulose systems. The strength of the cellulose fiber is retained, resulting in considerable flexibility during subsequent conversion, which includes newsprint, fiberboard, molded containers, corrugated boxes, and acoustical and other construction materials.

The separated crushed glass and light metals, approximately 10% by weight, has a sandlike consistency and "salt and pepper" appearance and is sold as aggregate for concrete, high-density fill, and road construction repair materials.

Rejected burnable materials are pulverized and are used to feed a flash furnace to provide heat for the dryers. Excess fuel may be used for other purposes in the future.[5]

Chapter III

IDENTIFICATION OF POTENTIAL VALUE OF REFUSE

A. General

Unfortunately there is no such thing as an average municipal waste composition; the composition varies from city to city. Most probably it also varies geographically from year to year, no doubt seasonally and temporarily, and even on shorter time scales, making definitive analysis difficult. There are, however, some general trends in composition that can serve as design input for technical and economic analysis. First, some nominal composition figures can be computed by using one's judgment along with the available data.

Recovery potentials fall into two basic groups of materials. The first group of items is labeled "mechanical recovery" and refers to that portion of the refuse system which is available for essentially mechanical extraction and for re-use as a relatively pure raw material. The second group includes what are primarily organic materials which, because of their physical characteristics, can only be recovered through conversion. Organic materials are generally suitable for chemical or biological conversion to a source of energy, either directly by burning or indirectly by converting to a storable fuel as in anaerobic digestion. Paper is included in both categories; some is recoverable as a material but some is not. This is due, in large part, to composite packaging (that is, paper laminated or otherwise attached to plastic or metal) and to the collection process. When mixed with other refuse, paper becomes contaminated with dirt, grease, and other materials that are unacceptable inputs to high speed paper making processes. Some of this portion of paper which is unsuitable for recycling as paper is acceptable as food for ruminant animals and the remainder for anaerobic digestion. Tests conducted by the United States Department of Agriculture, Division of Animal Nutrition, reported palatability and digestibility of paper is lowest with newsprint (40%) and highest with tissue and kraft paper (75%).[18] These test results were higher than those results reported in Australia.[27]

B. <u>Physical Composition</u>

Municipal refuse can be divided into two main physical categories which differ from its recovery potential: organic (mostly combustible) and inorganic (mostly noncombustible) materials. These are further separated into such physical components as putrescibles, paper, wood, plastics, grass and trimmings for the first category; and metals, glass, ashes, ceramics, stone, and dirt in the second category.

The methods of resource recovery of municipal refuse are also interrelated to the physical composition of the waste (see Table 3-1).

From Figure 1 (Mixed Perth Municipal Refuse Composition) it can be seen that most of the Perth municipal refuse (77%) falls into the "conversion recovery" bracket.

Figure 1

MIXED PERTH MUNICIPAL REFUSE COMPOSITION[8]

BY WEIGHT

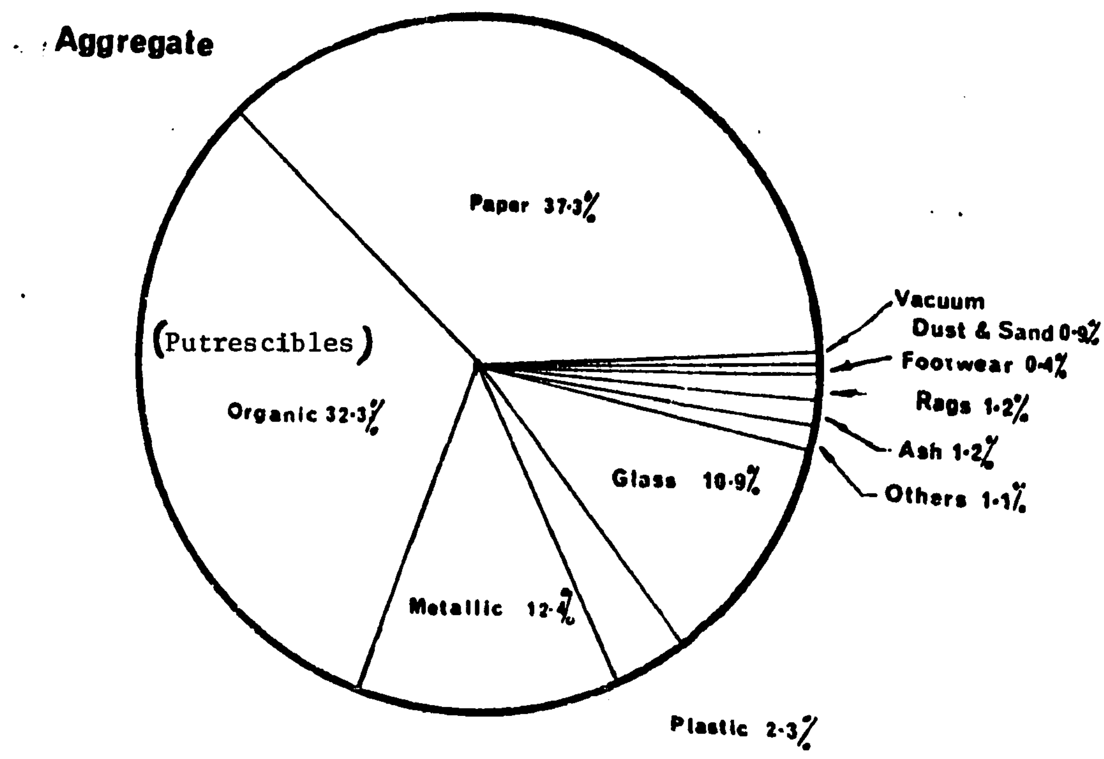


Table 3-1

EXPECTED PERCENT BY WEIGHT OF MUNICIPAL REFUSE COMPOSITION
IN PERTH, AUSTRALIA

Component	Recovery Potential	
Metallics	12.4	Mechanical Recovery (Metallics through Rags)
Glass	10.9	
Paper	37.3	Conversion Recovery (Paper through Miscellaneous)
Plastics	2.3	
Rags	1.2	
Organics (Putrescibles)	32.3	
Miscellaneous	3.6	

The refuse falling into the conversion recovery bracket can be further divided into these distinct components: (See Table 3-2)

used kraft paper

used newspaper

used wrapping paper

used magazines

wax and plastic coated paper (milk cartons, etc.)

tissue paper

lawn cuttings

starchy vegetables and meat

bread and cake

citrus

leaves and bark from eucalyptus trees

cloth (used clothing)

cooked beans and bone

cedar leaves

peels (onion, lettuce and apple)

fried fats (fish and chips)

cooked vegetables (garden peas)

cooked vegetables and eggs

swill (breakfast scraps from a hotel)

vacuum dust

leather (shoes)

fried potatoes

sawdust

plastic

Table 3-2

THE ORGANIC COMPONENTS OF
PERTH MUNICIPAL REFUSE DISAGGREGATED INTO TEST SAMPLE CATEGORIES

% of Totals		% by Weight (Wet)	% by Moisture	% by Digestibility	% Protein	Dry Weight (Tons)
23.13	Putrescibles					
	Raw Veg. Peels	3.47	83.5	97.2	17.38	.5725
	Cooked Veg.	3.47	76.1	92.6	16.18	.829
	Meat and Bones	3.47	58.0	88.8	60.79	1.457
	Fish & Chips	3.47	45.7	86.4	26.31	1.884
	Cake	1.16	17.8	91.0	5.73	.953
	Bread	2.31	36.3	94.7	16.99	1.471
	Starches & Meat	2.31	65.4	97.4	14.59	.799
	Citrus Seed & Rind	1.16	90.0	96.4	9.25	.116
	Fried Fats	2.31	81.2	98.3	67.48	.434
						8.52
37.3	Paper					
	Kraft	7.46	4.6	37.8	.45	7.117
	Newsprint	7.46	3.6	27.7	.21	7.19
	Magazines	7.46	2.9	36.9	.41	7.24
	Wrapping	7.46	6.2	39.1	.28	6.99
	Wax and Plastic Coated	3.73	5.1	31.3	3.94	3.54
	Tissue	3.73	10.4	31.9	2.61	3.54
						35.62
9.17	Lawn Refuse					
	Lawn Clippings	2.75	8.1	30.4	1.81	2.53
	Cedar, etc.	1.83	55.8	76.2	7.25	.808
	Tree Leaves & Bark	3.67	27.1	54.4	8.62	2.67
	Wood (Sawdust)	.92	7.7	24.9	10.62	.849
						6.86
4.8	Rags, Plastics, etc.					
	Rags	1.20	2.8	22.0	2.56	1.166
	Plastic	2.3	81.2	98.3	4.15	.43
	Leather	.4	10.2	49.3	42.18	.359
	Vacuum Dust	.9	4.4	40.0	23.62	.86
						2.81
	Swill	---	51.9	93.3	16.5	

(Swill is collected separately from the other municipal refuse and is not considered in those totals.)

C. Possible Toxicity or Other Harmful Effects on Animals

Refuse has been fed to any animal which would eat it since man first produced refuse. Until recently however, there was little concern about nutrition or toxicity. The bio-chemical composition of refuse has been analyzed during the past few years, therefore, we now have reliable information on the likelihood of materials toxic to animals being incorporated into rations formulated from municipal waste.

Dr. D. McKinnon of Oklahoma State University, Department of Agricultural Engineering, reported that sheep are more likely to pick up toxic levels of pesticides from grazing in the fields than from eating rations prepared from municipal refuse.[21]

Dr. G.G. Goluke of the Sanitary Engineering Research Laboratory of the University of California has conducted tests for heavy metals in the sludge from the anaerobic digestion of municipal refuse (as well as sewage). He reported that he found no heavy metals in municipal refuse sludge. Therefore, the possibility of animals being contaminated by eating rations prepared from municipal refuse would be remote.[22]

Dr. John F. Pseffer of the University of Illinois has tested the sludge from anaerobic digestion of solid waste. He reported the presence of heavy metals was less by "one power of magnitude" than in sewage digestor sludge. Iron is the only metal which was prominent.[23] Dr. Joe Bretrant of the Agriculture Research Center, Jay, Florida, conducted tests on heavy metal buildup in animals fed sewage sludge. In 1974 he fed six steers each 100 grams per day (dry weight) of sewage sludge from a digestor. After seven months he slaughtered the animals and examined their livers, kidneys, etc., and found that the test animals had a slightly higher content of lead in their livers than the control animal. No other symptoms could be found.[24]

There were no reports found in the literature of high concentration of heavy metals contamination in processed municipal refuse. The conclusion from the above research can only be that there is some danger in heavy metal buildup in animals fed with rations containing a large proportion of sewage sludge. However, rations containing products processed from municipal refuse could safely be fed to animals without danger of contamination from pesticides or heavy metal buildup.

D. Research on Digestibility and Nutrition

Perth Municipal refuse is classified as in Figure 1 and further subclassified into putrescibles (table scraps, etc.) with subcategories such as bread scraps, vegetable peels, etc. (see Table 3-2). There is a considerably higher percentage of food waste in Perth, Australia, than in Oklahoma City and United States averages (see Tables 3-2, 3-3, and 3-4). This is attributed to the absence of residential garbage grinders in Perth, and consequently the table scraps show up in their municipal refuse.

Test samples were all taken from refuse (not new material) and were then passed through a hammermill and aged for a minimum of one week at room temperature in order to duplicate actual conditions. Most samples had growths of fungus and mold; maggots were observed in some samples. Personal experience indicated that this represented the condition of refuse when it arrived at its destination; however, the refuse would not normally have been passed through a hammermill.

Paper other than newsprint and magazines had obviously been used for wrapping food or had been in contact with putrescribles. This was also true for wax and plastic coated paper, which had been used primarily as milk and soft drink cartons.

Table 3-3

PERCENTAGES OF TOTAL COMPOSITION[19]
OKLAHOMA CITY, OKLAHOMA - 1973

Category	Sample Number 1	2	3	4	5	Average
Glass	15.8	14.4	6.5	9.0	21.1	13.4
Plastic	3.2	9.0	6.5	5.9	3.6	5.6
Cans	15.5	4.3	16.4	4.8	7.9	9.8
Paper	31.9	36.8	40.8	33.5	42.1	37.0
Print paper, Cardboard	8.8	13.4	10.3	11.2	3.6	9.5
Putresc-ibles	21.3	20.4	16.1	29.8	12.9	20.1
Cloth	1.2	1.1	1.8	3.2	1.0	1.7
Wood	2.0	---	---	---	---	0.4
Rubber	---	---	---	---	---	---
Copper	---	---	---	---	---	---
Brass	---	---	---	---	7.1	1.4
Aluminum	0.3	0.6	1.5	2.9	0.8	1.2
Steel	---	---	---	---	---	---
Misc.	---	---	---	---	---	---
TOTAL	100.0	100.0	100.0	100.0	100.0	

Table 3-4

AVERAGE COMPOSITION OF MUNICIPAL WASTES IN U.S.A.[20]

Item	Average[1] (%)	Range of Reported Values (%)	
		Maximum	Minimum
Food	14.6	34.6	0.8
Garden	12.5	41.5	0.3
Glass	10.3	23.2	4.6
Metal	9.2	14.5	6.7
Paper	42.7	58.6	13.0
Plastics	1.7	3.3	0.7
Textiles	2.4	3.4	0.3
Wood	2.5	6.6	0.3
Leather, Rubber	1.8	4.7	0.8
Misc.	4.5	15.4	0.6

[1] Average of 24 reported values.

Samples from each category listed in Table 3-2 were tested for nitrogen by the Kjeldahl[25] method. _In vitro_ tests were also made for apparent digestibility. The method for _in vitro_ testing is well described in the literature.[17] Briefly, it consists of removing the moisture from the sample and first incubating it with remen fluid in a tube, and then reincubating the whole mass with pepsin.

In the above tests the results were correlated with _in vivo_ results which the Western Australia Department of Agriculture had kept over the past twenty-five years.[26] The results of these tests not only gave a reliable indication of the ability of a ruminant animal to digest the material, they also gave a good indication of the amount of decomposition to be expected in an anaerobic digestor.

The various organic components were then reaggregated into their composition in Perth municipal refuse. By these tests it was determined that the organic fraction of the refuse (i.e., putresciables, paper, lawn wastes and rags) has an apparent digestibility of 46.82 percent. (See Table 3-5)

Sheep should be able to subsist on this diet, although it is insufficient for lambing ewes; however, adequate nutrition remains in select organic fractions of the refuse to formulate desirable rations for lambing ewes.. (Table 3-6)[1] During 1974, J.B. Coombe experimented with feeding waste paper to ruminants.[27] He found that no toxic effects were present, but he reported more trouble in getting sheep to eat newsprint than any other paper. Since newsprint has a ready market, it should be recycled as paper, leaving relatively small quantities to be used in the sheep rations.

Research carried out by the United States Department of Agriculture[28] showed that sheep will eat materials in pellet form that they would otherwise avoid. Terrill[28] reported that pregnant ewes will put on more weight

Table 3-5

COMPOSITION OF 100 TONS OF PERTH MUNICIPAL REFUSE
(AGGREGATED INTO FOUR CATEGORIES)

Organics	% by Weight (Wet)	Dry Weight (Tons)	% Digestibility	% Protein
Putrescibles	23.13	8.516	93.99	26.40
Paper	37.3	35.416	35.51	.91
Lawn Refuse	9.17	6.859	44.38	6.15
Rags, etc.	4.8	2.812	42.67	13.15
TOTALS	74.4	53.603	46.82	10.05
Inorganics	25.6			
TOTAL	100.0 %			

Table 3-6

SHEEP RATIONS (DRY WEIGHT)

Composition		Tons	Digestibility %	Protein %
Paper	50%	10.0	35.51	.91
Putrescibles	27%	5.4	93.99	26.40
Swill	23%	4.6	93.30	16.50
TOTAL		20.0	64.58	11.40

with pelleted rations than by feeding on larger amounts of long hay (2.5 pounds pelleted is equal to 3 pounds unpelleted); a significant increase in fleece weight is also obtained, therefore these rations should be pelletized.

In the process of paper making most of the lignin is removed from the fiber leaving a high percentage of cellulose. Sheep are unable to digest lignin; therefore, the cellulose in paper is more readily available as an energy source than in untreated dry hay.[29] This could be the reason for the low digestibility of grass cuttings (30.4% compared to wrapping paper (39.1%). (See Table 3-2)

With an adequate energy source, sheep still require protein for cell growth. The nitrogen content of municipal refuse is a readily available source of protein for sheep. Test results in Perth show the putr fraction of municipal refuse to be 93.99% digestible and 26.43% protein. The high digestibility of the sample indicates that the nitrogen is available for use as protein. (See Table 3-6)

George Tomes, animal nutritionist, Muresk Agricultural College, Western Australia, confirmed that this ration in pelleted form is adequate for lambing ewes in Western Australian conditions.[1] (Sec Table 3-6)

E. Discussion of Perth Municipal Refuse Test Results

The high apparent digestibility of plastic (98.3%) is in contradiction to other reports in the literature. Part of this could be attributed to organic contaminants of the sample, plus microbal growth. The technician also reported that plastic is known to "wash out" in the *in vitro* tests, thereby causing an unreal apparent digestibility. The plastic also showed a high moisture content so that when it was reduced to dry weight proportions it represented less than 0.45% of the total composition. For these reasons it was decided to use the test results as recorded.

The lawn clippings were low in both digestibility (30.4%) and protein (1.81%). This is attributed to the fact that the samples were taken during the dry season.

Chapter IV

PROPOSED INTEGRATED SYSTEM

A. General

The development of methods used in the disposal of solid wastes, particularly municipal refuse, has been in a continuous state of flux for several decades. Processes involving greater degrees of technology encompassing mechanization, energy mass transfer, chemistry, and biology are being proposed as alternatives to those of a more conventional nature. Recognition of the fact that there is a hierarchy of material values in refuse is leading to the development of series processing. In effect, an individual process can be designed to remove a particular material component or fraction from the total waste stream. The successful operation of a totally integrated system involves the mutual compatibility of processes in which part of the waste stream accepts and/or rejects from preceding processing area in a form which can be passed along to subsequent stages. The stages in the total system should yield material and energy recovery consistent with optimum value return for processing and capitalization expenditures.

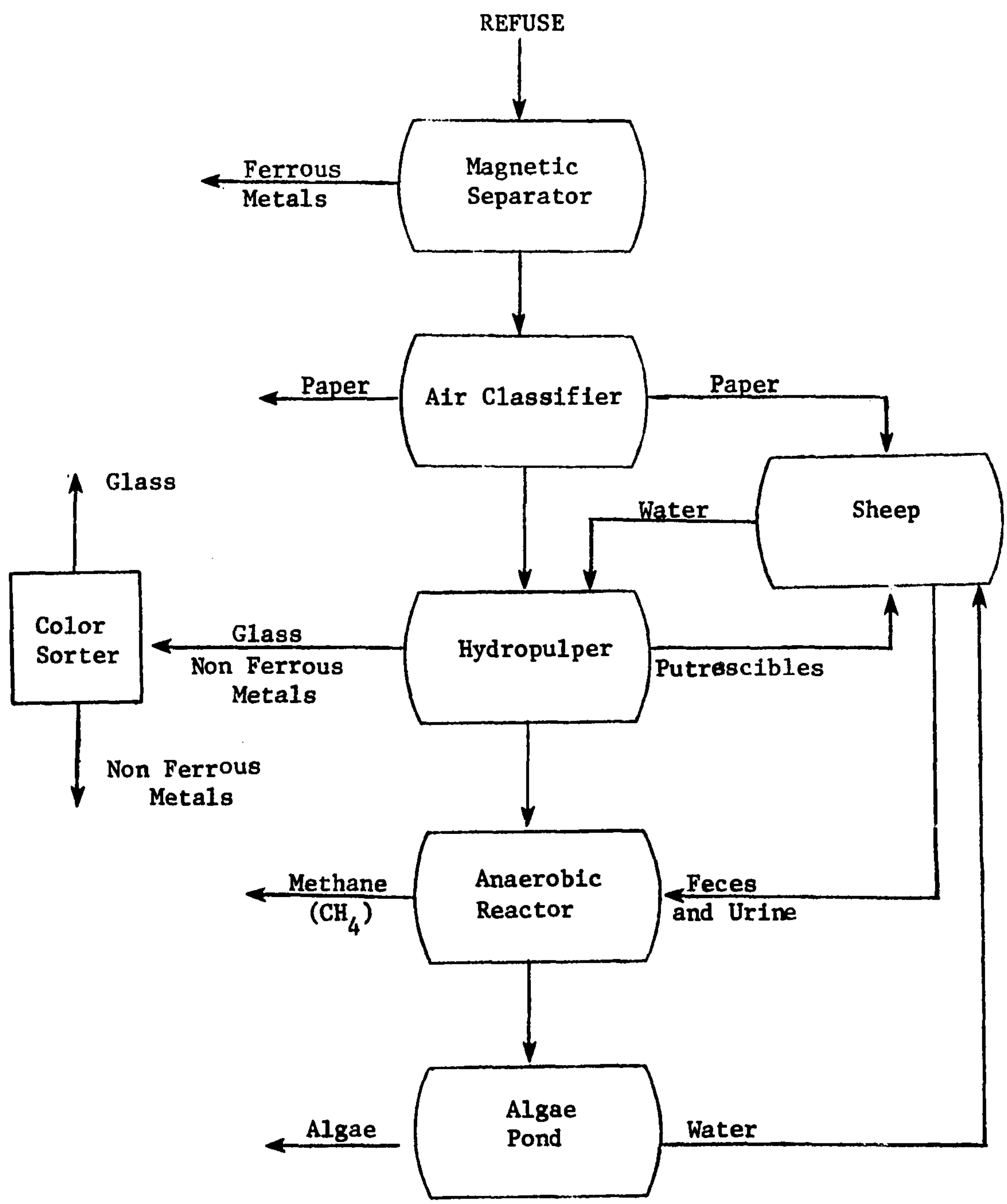
Biological conversion processing, specifically anaerobic digestion, is an important stage in this resource recovery system. The characteristics of methane production from sewage sludge as well as combinations of sludge and refuse have been the subject of research by a number of workers. For example, Kline[30] studied the anaerobic digestion of sewage sludge, and combinations of sludge and refuse ranging from 50% sludge and 50% refuse to 92.6% refuse and 7.4% sludge. The latter combination proved to be a limiting condition for unaided operation in terms of maintaining a suitable carbon-nitrogen ratio, acid-base balance, and nutrient composition for successful anaerobic digestion. Later Pseffer[23] considered the anaerobic digestion of shredded domestic refuse and raw sewage. In his experiments, a preliminary separation was made to remove glass and metal, and the levels of refuse and sewage input were proportional to the daily per capita production. In effect, since such a proportion resulted in a condition comparable to the limiting case reported by Kline, it was necessary for Pseffer to add nutrients and a base to his digestion process.

All researchers on anaerobic digestion of municipal refuse found in the literature survey considered it necessary to add nutrients to the organic fraction of municipal refuse in order for it to be properly decomposed by anaerobic fermentation. This was accomplished by adding sewage sludge for these nutrients. By adding these nutrients a desirable carbon - nitrogen ratio of approximately 30 was produced.

The system proposed here differs from most others in that it utilizes the feces and urine from ruminant animals (sheep) instead of sewage sludge as a nutrient (source of nitrogen). Furthermore, a portion of the refuse is pelletized and fed to these sheep. This requires a careful separation of the refuse in the initial stages. Most systems grind the refuse first, then separate it. This introduces large quantities of finely ground glass, plus paint, petroleum products, pesticides, and other potentially toxic material into the feed. The proposed system removes the portion to be used as sheep rations prior to grinding. Scavangers also remove bottles plus containers of paint, pesticides, etc., as well as batteries. (See Figures 2 and 3, "Schematic Flow Chart for the Proposed System", "Flow Chart for Municipal Refuse Processing System.") The System is based on 100 tons per day of municipal refuse; ten tons per day of "swill" collected from hotels and restaurants; ten tons per day of "Wheat dust" from wheat processing silos; an average of ten tons (dry weight) of tree prunings, plus builders' waste and special collections, averaging more than ten tons per day. The tonnage is calculated on a seven day week, i.e., hourly capacity for equipment for 100 tons per day = 100 x 7 ÷ 40 = 17.5 tons per hour in a forty hour week.

Figure 2

SCHEMATIC FLOW CHART FOR THE PROPOSED SYSTEM



See Figure 3 and Text for a Detailed Breakdown of the Processes Involved in the Proposed System.

FIGURE 3

FLOW CHART FOR MUNICIPAL REFUSE PROCESSING

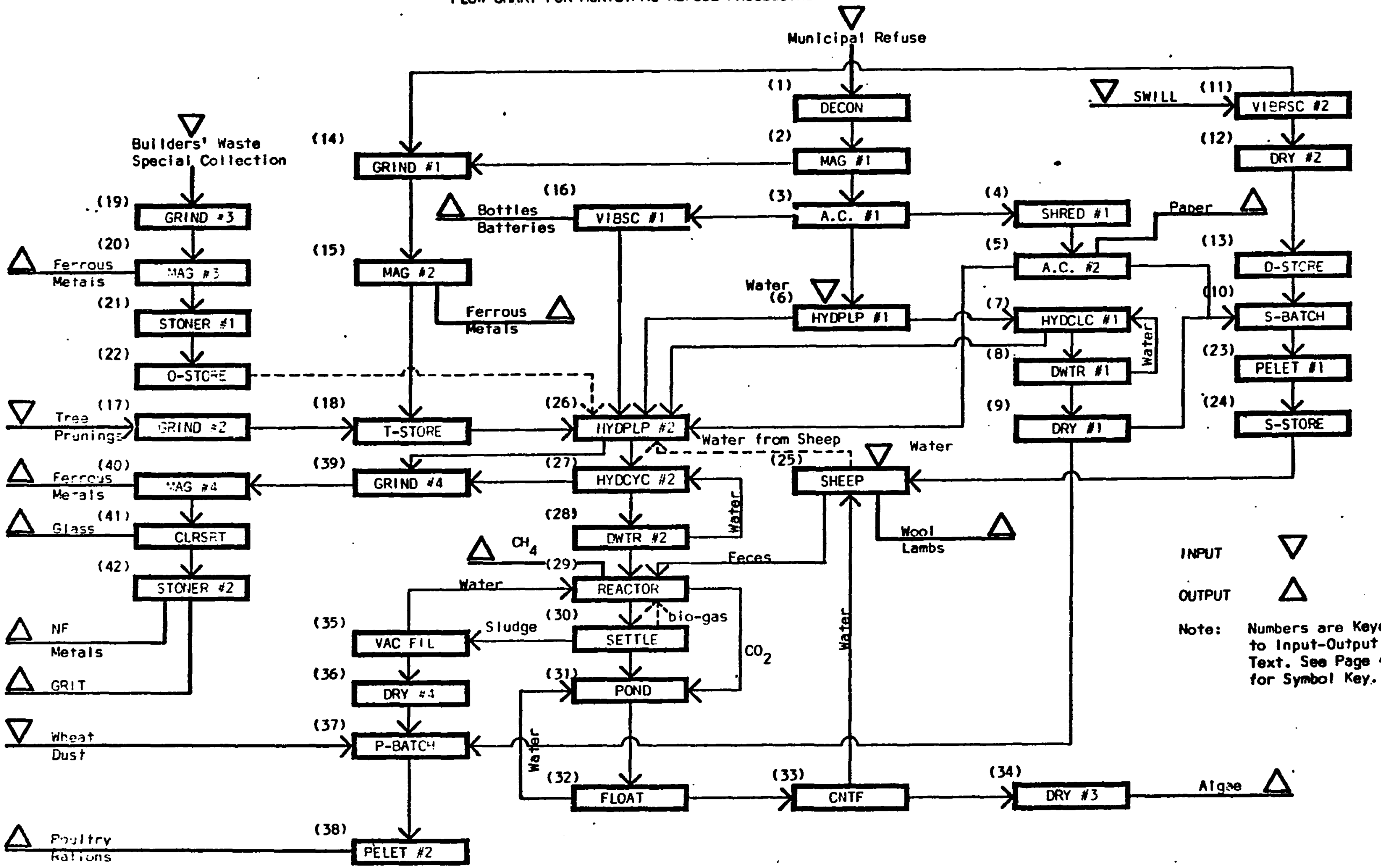


TABLE 4-1

SYMBOL KEY
KEY FOR SYMBOLS IN FLOW DIAGRAM NUMBER 1.

1.	DECON	Decontainerize
2.	MAG #1	Magnetic Separator #1
3.	A.C. #1	Airclassification Separator #1
4.	SHRD #1	Shredder #1
5.	A.C. #2	Airclassification Separator #2
6.	HYDPLP #1	Hydropulping Separator #1
7.	HYDCYC #1	Hydrocyclone Separator #1
8.	DWTR #1	Water Extractor #1
9.	DRY #1	Rotary Drum Dryer #1
10.	S-BATCH	Sheep ration Batch
11.	VIBR SC #1	Vibrating Screen Separator #1
12.	DRY #2	Rotary Drum Dryer
13.	D-STORE	Dried Swill Storage
14.	GRIND #1	Grinder #1
15.	MAG #2	Magnetic Separator #2
16.	VIBR SC #2	Vibrating Screen Separator #2
17.	GRIND #2	Grinder #2
18.	T-STORE	Tree Prunning Storage
19.	GRIND #3	Grinder #3
20.	MAG #3	Magnetic Separator #3
21.	STONER #1	Vibrating Table Separator
22.	O-STORE	Organics (wood) Storage

23.	PELET #1	Pelletizer
24.	S-STORE	Sheep Ration Storage
25.	SHEEP	Sheep Sheds
26.	HYDPLP #2	Hydropulping Separator #2
27.	HYDCYC #2	Hydrocyclone Separator #2
28.	DWTR #2	Water Extractor #2
29.	REACTOR	Anaerobic Reactor
30.	SETTLE	Quiescent Settling Tank
31.	POND	Algae Pond
32.	FLOAT	Algae Flotation Tank
33.	CNTF	Centrifuge Separator
34.	DRY #3	Rotary Drum Dryer #3
35.	VAC FILT	Vacuum Filter
36.	DRY #4	Rotary Drum Dryer #4
37.	P-BATCH	Poultry Ration Batch
38.	PELET #2	Pelletizer #2
39.	GRIND #4	Grinder
40.	MAG #4	Magnetic Separator
41.	CLR-SRT	Glass Separator by Color
42.	STONER #2	Vibrating Table Separator

B. Input-Output (See Flow Chart, page 41, Figure 3.)

1. Decontainerizer (DECON)

The municipal refuse is weighed and placed in a hopper from where it moves by a belt conveyer through the decontainerizer. The objective here is to free the refuse from plastic bags, boxes or other constraints so that discrete items such as tin cans, bottles, paper, etc., may be exposed to the separation and classification equipment. DECON consists of upper and lower belt conveyors equipped with teeth and moving at different speeds. Such items as bags or boxes passing between the two belts are ripped apart by the teeth. Two men are stationed at DECON to remove any material which likely could not be processed by the equipment and to open bags, boxes, etc., which DECON failed to properly rip apart.

Input

100 Tons of municipal refuse per day = (100 x 7 ÷ 40)

17.5 tons per hour

Output

100 Tons per day of municipal refuse which has been removed from its containers of bags, boxes, etc.

2. Magnetic Separator #1 (MAG #1)

The material in the waste stream is now unrestrained. Therefore, magnetic action can pick up more than 95 percent of the ferrous metals. Some of these metals are laminated or otherwise attached to

---

Note: Numbers appearing in the text are keyed to the Flow Chart on page 41 . For example, the description above of 2. Magnetic Separator, corresponds to (2) on the Flow Chart.

paper, wood, plastic, and glass. These contaminants amount to approximately one ton, which is considered as paper.

Input

100 tons of municipal refuse

Output

11 tons of contaminated ferrous metals

The remaining 89 tons pass through air classification separator number 1 (AC #1).

3. Air Classification Separator #1 (AC #1)

The remaining refuse material is dropped through a horizontal moving stream of air. The heavy dense material ("heavies") such as batteries, castings, full or partially full containers made of metal, glass, plastics, wood, or laminates, along with most glass, china, ceramics, and heavy plastics, will fall through, along with heavy putrescibles and footwear. These "heavies" move along a train to a vibrating screen separator (VIBSC #1).

An intermediate fraction ("middies") of the refuse material consisting of putrescibles, wax coated paper, plastics, etc., is blown onto a conveyor and moved to hydropulper number 1 (HYDPLP #1). The lighter fraction ("lights") is sucked past this conveyer to a shredder (SHRD). This separator (AC #1) was developed by the United States Bureau of Mines and is operated in Edmondston, Maryland.[33]

Input

89 tons of municipal waste minus ferrous metals

Output

	Heavies	Middies	Lights
Putrescibles	7	15	0.13
Paper	3	3	30.3
Lawn Refuse	1	1	7.17
Rags, Plastics, etc.	0.4	2	2.4
Glass	10.	0.9	---
Ferrous Metals	---	---	---
Non-ferrous Metals	0.5	0.8	0.7
Ashes, grit, etc.	1.1	1.2	---
	23	24	40.7

4. Shredder #1 (SHRD #1)

This equipment is in common use for shredding paper prior to high density bailing and/or air classification.

Input

41 tons of paper, plastics, etc.

Output

41 tons of shredded paper, plastic, etc., reduced to four inch size.

5. Air Classification Separator #2 (A.C. #2)

This equipment separates the heavy fraction from the light fraction by air density. Such equipment was developed by Radar Pneumatics and has been used in a St. Louis plant since 1972.

Input

41 tons of shredded paper, plastics, etc.

Output

20 tons of "light fraction" paper

13 tons to sell

7 tons for sheep rations to S-BATCH

20.7 tons of paper, plastics, etc., to HYDPLP #2,

consisting of:

Putrescibles	0.13
Paper	10.3
Lawn Refuse	7.17
Rags, plastic, etc.	2.4
Non-ferrous metals	0.7
	20.7

6. Hydropulping Separater #1 (HYDPLP #1)

A solid waste hydropulper pulps organic material by water jet action and rotating blades in a conical container, which produces a vortex action. Such a system was developed by the Black Clawson Company, with the support of the E.P.A.,[32] and has been in operation in Franklin, Ohio, since 1971. In the Franklin plant, the refuse is charged as collected, except that bulky, readily separated materials have been removed. The mixture is shredded and pulped, the non-pulpable materials (cans, ceramics, stone, etc.) are separated out by a "junk" remover.

The organics introduced into HYDPLP #1 are to be used in the sheep rations. The most undesirable materials for animal rations (bottle,, cans, batteries, paint and glass) have been removed in the "heavies" train.

Input

24 tons per day of refuse (as collected)

112 tons water

Output

Dry Weight, Tons	To HYDCYC #1	To HYDPLP #2
Putrescibles	5.8	---
Paper	2.9	---
Lawn Refuse	.3	.7
Rags, plastic, etc.	.16	1.0
Glass	.4	.5
Ferrous metals		
Non-ferrous metals		.8
Ashes, grit, etc.	.7	.5
Water	112	
TOTAL	122	3.5

7. Hydrocyclone Separator #1.

A hydrocyclone operates on the same principal as other cyclones, except the medium is water rather than air. The heavy material (glass, metal, etc.) is removed by centrifugal action.

Input

10.26 tons (dry weight) of refuse

161 tons water

Output to	To DWTR #1	To HYDPLP #2
Putrescibles	5.8	
Paper	2.9	
Lawn Refuse	.3	
Rags, plastic, etc.	.16	
Glass		.4
Ferrous metals		
Non-ferrous metals		
Ashes, grit, etc.		.7
Water	161	
Dry =	9.16	1.1

8. Water Extractor #1 (DWTR #1)

This water extractor consists of an inclined tube with a helix screw. Pulp is pulled up by the screw while the water flows back, reducing water content to 83 percent. This system was developed by the Black Clawson Company and is in use in the Franklin, Ohio, plant.

Input

161 tons water

9.16 tons organics

Output

109.5 tons water

54.0 tons of organics 83% water

9. Dryer #1 (DRY #1)

This organic material must be dried at a low temperature

(49° C) to prevent denaturization of the protein. Such dryers are in common use in the food industry.

Input

54 tons - 17 percent dry

Output

18.3 tons - 50 percent dry

8.7 tons to sheep ration batcher (S-BATCH) consisting of 5.4 tons putrescibles, 3 tons of paper, and 0.3 tons of grass, plastic, etc., plus 0.5 tons to poultry ration

10. Sheep Ration Batcher (S-BATCH)

The correct proportion of paper, putrescibles, and dried swill for the sheep rations are blended in S-BATCH.

Input

Paper, swill, putrescibles

Output

20 tons (dry weight) of sheep rations to the pelletizer (PELET #1)

11. Vibrating Screen Separator #2 (VIBRSC #2)

This equipment consists of a vibrating screen with a three-inch mesh. This will strain most glass, metals and plastics from the swill.

Input

10 tons of swill

Output

0.5 tons of metal, glass, etc., to GRIND #1

9.5 tons of swill to DRY #4

12. Dryer #2 (DRY #2)

This is the same equipment as DRY #1; the numbers have been changed in order to identify the input.

Input

9.5 tons of swill - 52 percent moisture

Output

4.6 tons of dried swill to D-STORE

13. Dried Swill Storage (D-STORE)

D-STORE is a storage bin for dried swill. A sufficient supply of dried swill may be safely kept to provide the correct proportion of nutrients to the more perishable fifty percent moisture content of putrescibles arriving at S-BATCH.

Input

Dried swill - 4.6 tons

Output

Dried swill - 4.6 tons

14. Grinder #1 (GRIND #1)

This equipment is used in most solid waste treatment plants. The objective is size reduction. The minimum capacity is 15 tons per hour.

Input

11 tons contaminated ferrous metal

Output

11 tons of ground ferrous metal to MAG #2

15. Magnetic Separater #2 (MAG #2)

This equipment was described under MAG #1.

Input

11 tons contaminated ferrous metals

Output

10 tons ferrous metal to be sold

1 ton paper to HYDPLP #2

16. Vibrating Screen Separator #1 (VIBRSC #1)

The heavy fraction from AC #1 is conveyed onto a vibrating two-inch screen belt conveyor where two scavengers (marine merchants) recover intact bottles (local government does not allow returnable bottles to be ground for cullet) and other containers, such as paint, which might be toxic to the micro-flora. Small batteries fall through the two-inch screen and are removed. Studies by the Illinois Institute of Technology indicate that there would be less than 100 pounds of batteries per day. It is desirable to remove these heavy metals, even though there is no known market for bateries in Perth. They may be safely disposed of in a sanitary landfill, along with the miscellaneous containers.

Input

23 tons per day

Putrescibles	7
Paper	3
Lawn Refuse	1
Rags, plastics, etc.	.4
Ferrous metals	---
Non-ferrous metals	.5

Glass	10
Ashes, grit, etc.	1.1
	23

Output

Bottles	1 ton
Batteries	0.045 tons
Miscellaneous containers	.3 tons
	1.3 tons

The remaining 21.7 tons of heavy refuse is conveyed to hydropulper separator number 2 (HYDPLP #2).

17. Grinder #2 (GRIND #2)

This is the same equipment as GRIND #1; different numbers are used to identify the input.

Input

10 tons (dry weight) of tree prunnings. This is an average figure. The equipment will not be used for this purpose each day.

Output

10 tons ground organics to T-STORE for HYDPLP #2.

18. Tree Pruning Storage (T-STORE)

Since tree pruning is intermittent, the ground/prunings are stored here so that the required 10 tons per day may be fed to HYDPLP #2.

Input

Intermittent ground/tree prunings.

Output

10 tons per day of ground/tree prunings to HYDPLP #2

19. Grinder #3 (GRIND #3)

This is the same equipment as grinders one and two.

Input

Builders waste and special collections. Quantities for these wastes cannot be determined since they vary with the economy, seasons, governmental policy, and many other social factors.

Output

Ground organics (mostly wood), masonry, metals, glass, and laminated material.

20. Magnet #3

The same equipment as magnet number two. The number is changed to identify the input.

Input

Organics, metals, glass, etc.

Output

Ferrous metals to sell.

Organics, glass, etc., to STONER #1

21. Vibrating Table Separator #1 (STONER #1)

This equipment is widely used in mining and agriculture to separate materials by density and shape.

Input

Organics (mostly wood)

Inorganics (glass, masonry, etc.)

Output

The organics are separated and stored to be used in the anaerobic reactor when the nitrogen content of the waste materials is high enough to utilize the high carbon content of this material, and at the same time maintain a desirable carbon-nitrogen ratio in the anaerobic reactor. Inorganics consisting of masonry, grit, glass, etc., can be used in construction work as ballast (fill). No income has been calculated for this.

22. Organic (wood) Storage (O-STORE)

The organics from the builders' waste and special collection has been ground and stored here for use in the REACTOR. The organics coming from builders' waste and special collections consist primarily of ground wood.

23. Pelletizer #1 (PELET #1)

This equipment is widely used in the animal food industry. Ground organics are forced through a die with steam and pressure. The operating temperature is sufficient to destroy salmonella and prevent the food from being contaminated by aflatoxin.[42] The resulting pellets contain less than ten percent moisture and may be safely stored.

Input (dry weight)

Paper	10 tons
Putrescibles	5.4 tons
Swill	4.6 tons
	20.0 tons

Output

20 tons of pelleted sheep rations

24. Sheep Ration Storage (S-STORE)

Sufficient quantities of sheep rations are kept here to last seven days in case of supply shortages or stoppage. (7 x 20 = 140 ton capacity)

Input

Sheep rations

Output

Sheep rations to sheep sheds (SHEEP) - 20 tons per day

25. Sheep Sheds (SHEEP)

These sheds are roofed and have a slatted floor. Beneath the slats is water, approximately one foot deep (2400 tons). The feces and urine pass between the slots in the floor and into the water where the anaerobic bacteria in the feces survives. The feces and urine are transported to the REACTOR in the water.

Input to 15,000 sheep

20 tons of rations per day

Output

24,000 lambs per year to sell

100,140 kilo (220,300 lb) of wool per year to sell

7.707 tons (dry weight) feces and urine per day for the REACTOR

Water for transporting feces to REACTOR

26. Hydropulping Separator #2 (HYDPLP #2)

The following materials are pulped and separated in HYDPLP #2:

Input

50 tons (dry weight) consisting of the following:

Source	VAC Fil #1	VIBRSC #1	T-STORE	AC #2	HYDPLP #1	HYDCYC #1
Putrescibles		2.58		.05		
Paper		2.9	1	10.0		
Lawn Refuse		.75		5.36	.7	
Rags, Plastic, etc.		.116		1.39	1.0	
Ferrous Metal						
Non-ferrous Metal		.5		0.7	.8	
Glass		9.			.5	.4
Ash, grit, etc.		1.			.5	.7
Tree Prunings			10			
Water	112					
TOTAL DRY WEIGHT	(49.946)	16.846	11.0	17.5	3.5	1.1

Output To GRIND #4

Glass 9.6

Non-Ferrous Metal
1.8

Rags, plastics, etc.
1.7
13.1 tons

To HYDCYC #2 = 36.9 tons

27. Hydrocyclone Separator #2 (HYDCYC #2)

1195 tons (36.9 tons solids) are passed through HYDCYC #2 where 1.1 tons of inorganics are removed. The remaining 35.8 tons (dry weight) of organics are pumped into water extractor number 2 (DWTR #2).

Input

1195 tons (36.9 tons solids)

Output

1.1 tons inorganics

28. Water Extractor #2 (DWTR #2)

This is the same equipment as DWTR #1 and is as described there. The reason for different numbers is to identify the product.

Input

1194 tons (35.8 tons dry weight)

Output

917 tons of water recycled to HYDPLP #2

477 tons at 7.5 percent solids to the anaerobic reactor

= 35.8 tons (dry weight) organics

inorganics

29. Anaerobic Reactor (REACTOR)

This consists of a closed, stirred tank held at 39° C where anaerobic fermentation takes place.

Input

44.576 tons (dry weight) of organics

See Tables 4-1 and 4-2 , pages 60 and 61 (Analysis of Elements of Anaerobic Reactor Input) and (Weight Per Element of Anaerobic Reactor Input) for detailed analysis of input.

Quantities of methane and cell growth were arrived at using methods of McCarty.[36] The amount of oxygen required to convert a definite amount of an organic compound to carbon dioxide, water and ammonia is represented by the formula:

$$C_nH_aO_bN_c + (n + \frac{a}{4} - \frac{b}{2} - \frac{3}{4} C)\ O_2 \rightarrow nCO_2 + (\frac{a}{2} - \frac{3}{2} C)\ H_2O + C\ NH_3 \quad ^{35}$$

The empirical composition for the anaerobic reactor input can be expressed as $C_{29}\ H_4\ O_{22}\ N_1$. The oxygen required to convert 44.573 tons of this compound would be 36.237 tons x 2240 = 81,171 pounds. The amount of volatile biological solids (consisting primarily of microbal cells) can now be projected.

$$A = \frac{a\ F}{1 + b\ (SRT)} \quad ^{36}$$

where F = lb. BOD (81,171 lb)

a = growth constant (.2143)

b = endogenous respiration rate (.0313)

SRT = detention time (10 days)

A = 13,248 lb. volatile biological solids.

Table 4-2

ANALYSIS FOR ELEMENTS[39]
OF ANAEROBIC REACTOR INPUT

	Dry Weight-Tons (2240 lbs)	%	C	H	O	N	Ash	S
Putrescibles	3.116	6.99	41.7	5.8	27.6	2.8	21.9	.25
Paper	13.016	29.20	-45.4	6.1	42.1	0.3	6.0	.12
Yard Waste	6.859	15.39	49.2	6.5	36.1	2.9	6.0	.35
Rags, etc.	2.812	6.31	46.2	6.4	41.8	2.2	3.2	.2
Sheep feces	8.70	19.52	49.0	6.1	24.0	3.0	17.21	-
Sheep urine	.07	.16	4.0	-	-	95.0	-	-
Tree pruning, etc.	10.00	22.43	49.6	6.2	38.5	0.201	5.5	-
	44.573							

Table 4-3

WEIGHT PER ELEMENT

OF ANAEROBIC REACTOR INPUT

	Tons	%	C	H	O	N	Ash
Putrescibles	3.116	6.99	1.30	.18	.86	.087	.682
Paper	13.016	29.20	5.91	.79	5.49	.039	.781
Yard waste	6.859	15.39	3.375	.446	2.476	.199	.343
Rags, etc.	2.812	6.31	1.299	.1799	1.175	.0619	.090
Sheep feces	8.70	19.52	4.263	.5307	2.088	.261	1.153
Sheep urine	.07	.16	.0028	-	-	.0665	-
Tree prunings, etc.	10.0	22.43	4.96	.62	3.85	.0201	.55
TOTAL	44.573		21.11	2.7466	15.939	.7345	3.59

∴ C/N Ratio = 21.11 ÷ .7345 = 28.74

Volatile Solids (VS) = 92%

The empirical expression for the above composition is

$$C_{29}\ H_4\ O_{22}\ H_1$$

The values for a and b were arrived at by assessing the compound to be 85% carbohydrates, 10% proteins, and 5% fatty acids, then interpolating from McCarty's data. *

The amount of methane (CH_4) was then predicted:

$C = 5.62 \ (e \ F - 1.42 \ A)$[36]

$C = CH_4 \ ft^3$

e = efficiency (95%)

F = BOD added per day (81,171 lbs.)

A = volatile biological solids (13,248.6 lbs.)

$C = 420,000 \ ft^3$

This compares favorably with tests conducted over the past several years by the U.S.D.A. in Peoria, Illinois,[37] with a loading of 7.5 percent solids and a detention time of ten days. A mass reduction of 65 percent was recorded. Gas production was 8.75 ft^3 per pound of volatile solids. Therefore, 99,843 pounds at 92% volatile solids would produce 803,740 ft^3 of gas. This was recorded as 52% Ch4 or 417,944 ft^3 of CH4.

Output

420,000 ft^3 CH_4 to sell

594 tons of degassed effluent containing microbial cells and undigested organics to SETTLE

*Note: A computer program was prepared for the above for sensitivity analysis. The carbohydrates, proteins and fatty acids were each varied from five percent to eighty-five percent. Methane production varied less than ten percent.

30. Quiescent Tank (SETTLE)

Input

594 tons of effluent from the REACTOR

Output

17.8 tons (dry weight) of sludge (40 percent of input)

5.9 tons (dry weight) of this is biological volatile solids

The nitrogen flow can now be determined.

44.573 tons x 2240 = 99,843.5

@ 1.61% nitrogen = 1,607.5 lbs

13,248 lbs. of biological volatile solids assessed as

50 percent protein = 6624 ÷ 6.25 = 1,059.84 lbs of nitrogen

This nitrogen appears in the sludge; the balance (547.16 lbs) is expected to pass off with the 416 tons of effluent to the algae ponds.

31. Algae Pond (POND)

Algae, through photosynthesis, can utilize nitrogen and other nutrients, plus sunlight, as energy to produce organic cells containing fifty percent to eighty percent protein. This is desirable in that usable protein is produced and the BOD of the effluent is reduced so that the water may be recycled through the system. The University of California has cultivated algae protein grown on the supernatant (effluent) from an anaerobic digestor and successfully fed it to animals since 1960.[41]

Spirulina is a desirable algae in that it floats and is relatively large, making it easier to harvest than most other algae.[40-41] Another advantage is that it has been grown and harvested for many years in North Africa and Mexico so that its characteristics are now well known. Dr. Michale Ruane, microbiologist of Perth, Western Australia, reports that spirulina exists in Western Australia and that a true culture could be maintained under proper conditions.[40]

This POND consists of plastic tubes eight inches deep and sixteen feet wide. Approximately thirty acres surface area is required.[4-15]

There is 547.66 lbs of nitrogen available for algae growth. Algae of fifty percent protein would have eight percent nitrogen, i.e., $547.66 \div .08 = 6{,}845.77$, or 3.06 tons (dry weight) per day of algae containing fifty percent protein.

Input

416 tons of effluent

22,000 tons of water (548 tons from sheep sheds)

Output

22,416 tons of algae-water mixture.

32. Flotation Tank (FLOAT)

Since spirulina floats, the algae slurry may be recovered by auto flotation from a shallow pond.[41]

Input

22,416 tons of water containing algae

Output

Algae slurry at 2,000 m/l (0.2%)[41] = 1,525 tons to CNTF #1

Algae water returned to POND = 22,416 - 1,525 - 10% loss

= 18,800 tons containing unharvested algae

33. Centrifugal Separator #1 (CNTF #1)

This equipment is frequently used for extracting microscopic material such as algae. Its disadvantage is high maintenance and energy costs. Spirulina has been successfully separated by filtering in Mexico and Africa. However, the Australian variety is somewhat smaller than the American or African counterpart.[40] Since there is no record of successful filtering, the more expensive centrifugal separator system will be used here.

Input

1,525 tons of algae slurry containing 3.05 tons dry weight of algae

Output

Consider 90 percent harvesting efficiency and 30 percent algae = 9.15 tons to Dryer #3 (70 percent moisture)

34. Dryer Number Three (DRY #3)

This is the same equipment as dryers one and two. The numbers have been changed in order to identify the input.

Input

9.15 tons of algae slurry - 70 percent moisture

Output

2.75 tons of dry algae to sell

35. Vacuum Filter #1 (VAC FIL #1)

This equipment is in common use in sanitary engineering. A filter on a revolving drum is passed through the sludge and over a vacuum, with the result that sludge accumulates on the filter. The filtered sludge contains approximately 25 percent solids and can be scrapped from the filter. A sludge thickening agent may be used to increase efficiency. This can be determined by testing the sludge.

Input

178 tons of sludge - 10 percent solids

Output

71.2 tons of sludge - 25 percent solids to DRYER #4

106.8 tons of water to HYDPLP #2

36. Dryer #4 (DRY #4)

This is the same equipment as dryers number two and three. The number is changed to identify the input.

Input

71.2 tons of sludge

Output

17.8 tons of dry sludge to be stored for P-BATCH

37. Poultry Ration Batcher (P-BATCH)

This is the same as the sheep ration batcher, except that the ingredients are dried sludge, wheat dust and putrescibles.

Input

17.8 tons of sludge

10 tons of wheat dust

0.4 tons of putrescibles

Output

28.2 tons (dry weight) of poultry rations

38. Pelletizer #2 (PELET #2)

This is the same equipment as PELET #1; the number has been changed to identify the input.

Input (dry weight)

sludge - 17.8 tons

wheat dust - 10 tons

Putrescibles - 0.4 tons

Output

28.2 tons of pelleted poultry rations

39. Grinder #4 (GRIND #4)

This is the same equipment as grinders one, two and three. The number is changed to identify the input.

Input

14 tons of inorganics from HYDPLP #2 and HYDCYC #2

Output

14 tons of inorganics to MAG #4

40. Magnetic Separator #4 (MAG #4)

This is the same equipment as magnetic separators two and three.

Input

14 tons of inorganics

Output

1 ton ferrous metal to sell

13 tons glass, etc., to color sorter (CLR-SRT #1)

41. Color Sorter (CLR-SRT #1)

This equipment passes a material between an optical scanner and a background. If the material matches the background a jet of air moves it off its trajectory. Other materials continue on. In this manner, glass may be sorted into clear amber and green. Other materials continue on the train. This equipment is operating in Franklin, Ohio.

Input

13 tons of glass, etc.

Output

9.8 tons glass

= 3.2 tons to STONER #2

42. Vibrating Table Separator #2 (STONER #2)

This equipment was described under STONER #1.

Input

3.2 tons of inorganics

Output

1.8 tons of non-ferrous metals to sell

1.4 tons of grit, masonry, etc., for fill

Summary of Input-Output

Input:

100 tons of municipal refuse

10 tons of swill

10 tons of wheat dust

10 tons (dry weight) of tree prunings

10 tons (min.) of builders' waste and special collections

140 tons of waste daily (Total waste input)

Solar energy	
anaerobic reactor heating	54.0×10^6 BTU's/day
algae growth	30 acres of surface
Electrical energy for equipment	7,250 KWH/day
Manpower (including knowledge)	27 per day
Equipment	$1,000,000
Land	100 acres
Water	-------------------
Air	-------------------

Output:

Non-ferrous metals	1.1 tons per day
Ferrous metals	10 tons per day
Paper	13 tons per day
Methane	420,000 ft^3 STP per day
Wool	100,140 kilo (220,300 lbs) year
Lambs	24,000
Glass	10 tons per day
Algae	2.75 tons per day
Poultry Feed	28.2 tons per day

A market has been established for the above products. However, no market has been established for the grit (5% of glass and metals which were not recovered and show up as grit.) This is true for ash, sand, ceramics, and masonry. Not considering builders waste and special collection, there would be five tons of grit with the following composition:

Metals 12.4 @	=	.6
Glass 10.9 @	=	.5
Rags, plastic, etc.	=	1.6
Ash, Sand, etc.	=	2.3
TOTAL	=	5.0 tons

The local government has agreed to use this amount as fill in construction projects. No income was calculated for the builders waste and special collections. However, these wastes should produce a profit when processed through the system. Builders waste consists basically of wood and masonry with some metals. The wood can be ground and used in the REACTOR thereby increasing the production of methane, algae and sludge. The metals can be separated and sold. The masonry can be reduced in size in the grinder, it is then suitable for ballast (fill) in construction work. Special collections contain white goods (refrigerators, stoves, etc.) plus other discarded furniture and equipment. The grinding equipment is sized to handle refrigerators, stoves, etc. (not automobiles). After these materials have been reduced in size by the grinding equipment they can be sold along with the other scrap metal.

Chapter V

ECONOMIC STUDIES

A. Present Waste Disposal Problems in the Perth Metropolitan Area

A report commissioned by the Public Health Department and prepared by the technical advisory subcommittee of the Metropolitan Refuse Disposal Planning Committee was commenced in October 1970 and accepted in May 1974.[8] This report concluded that waste management costs (collection and disposal) will rise whatever methods are adopted in the future, and that increasing financial contribution must be made by the local community.

Furthermore, the disposal of waste by the landfill method must continue at present. However, the situation in respect to the availability of land in the metropolitan area for disposal by this means now appears to have a much more limited future than indicated by earlier estimates.

Therefore, the introduction of supplementary methods to increase refuse density (static compactors, pulverization or shredding), together with transfer stations is needed in order to increase the effective life of usable disposal sites and to enhance the 'pay load' of transport vehicles. The introduction of incineration was considered but for environmental and economic reasons it is not currently a practicable proposition.

An economic study was included in the above report on the costs of shredding, separating and compositing Perth municipal refuse. These costs along with the studies on the composition of refuse are used as a basis for this study.[8,33,34]

B. <u>Economic Considerations of the Proposed Project.</u>

1. <u>Introduction</u>

It is necessary to have a demand for a product; otherwise, it becomes refuse. For this reason, a study was made of the demand for each product. It was found that there is local demand for the products, and letters of intent to purchase have been obtained.

Schedule 1, Appendix A is the result of this survey and the ba pricing. The succeeding schedules detail the individual products.

2. <u>Capital Costs</u>

From the Input-Output data it was possible to determine the types of equipment required and its capacity. From this information a survey was made of equipment manufacturers, from which Table 5-1, page 73 "Major Equipment Details" was prepared. These prices represent approximate factory costs from best manufacturer estimates, and actual equipment costs submitted for similar projects[38] and similar equipment in existing plants, particularly the facilities in Franklin, Ohio and St. Louis, Missouri.

To the basic equipment costs, 20% was added for micellaneous ancillary equipment. A further 43% was added for installation costs. Then $100,250 was added for transportation to Australia (the cost of a "stretched 8" cargo plane from Oklahoma City to Perth).

Actual building costs were estimated by quantity surveyors in Australia. Due to the technical nature of the project a fee of 23% was used for architect and engineers fees, this includes full construction supervision. A further $100,000 was allowed for feasibility studies.

Table 5-1

MAJOR EQUIPMENT DETAILS

Name	Capacity (Tons/Hour)	Approx. Cost (U.S. $)	Manufacturer
Decontainerizer	20	15,000	Lumis Gin*
Airclassification Separator #1 (including Magnetic Sep. #1)	20	139,000	Radar Pneumatics
Magnetic Separators #2, 3	5	5,200	General Electric
Airclassification Separator #2	10	95,000	Radar Pneumatics
Shredder	10	17,000	Williams
Vibrating Screens	10	10,000	Lumis Gin
Hydropulper #1 (including Hydrocyclone & dewatering)	5	17,000	Black Clawson
Hydropulper #2 (including Hydrocyclone & dewatering)	15	90,000	Black Clawson
Grinders	15	105,000	Williams
Color Sorter	5	15,000	Sortex
Centrifuge	207	76,000	Dorr-Oliver
Vacuum Filter	35	55,000	Dorr-Oliver
Pelleting Plant	35	20,000	Calif. Pellet Co.
Pumps	30	7,500	Zecussi
Dryers	10	75,000	Black-Clawson
Stoner	4	15,000	Sutten, Steel & Steel

Table 5-1

(Continued)

Name	Capacity (Tons/Hour)	Approx. Cost (U.S. $)	Manufacturer
Reactor Instrumentation	---	10,000	Dorr-Oliver
Reactor Solar Heater	---	23,000	Solar Hart**

*Modified Standard Equipment.

**The solar heater is furnished in Australia.

Note: Prices are factory prices in the United States using U.S. dollars and do not include transportation, installation, taxes, etc.

3. Labor Costs

From the Input-Output data, equipment lists and worker analysis the labor costs were estimated using plants with similar capacity and local conditions in Perth as a basis. (See Table 5-2 Manpower requirement).

4. Energy Costs

From Input-Output data and equipment capacities the energy requirements were estimated. The horsepower of the equipment and the time in use was converted to killowatt hours (KWH). 20% was added for miscellanous demands. By using $.04 per KWH, this totaled $212,500 per year.

5. Maintenance

Labor cost for maintenance was included in man power requirements. Therefore, replacement parts only are included. For the first year the equipment is under warranty, thereafter $40,000 yearly is allowed for replacement parts.

6. Capital Expenditure

Equipment (including installation)	$1,064,110
Algae ponds	114,400
Fermentation tanks	165,000
Solar heaters for fermentation tanks	17,160
Sheep sheds	117,000
Plant buildings	120,000
Fees	525,000
Land	100,000
Sheep	160,000
Total	$2,382,670

7. Cash Flow

After the expenses and revenues were determined, a cash flow was prepared. See Table 5-3 . The equipment coming from the United States was considered as financed by the Export-Import Bank (EXIM Bank) with a 20% deposit and the balance over 5 years at 10% interest. The engineering work is completed under the column labeled engineering. At the beginning of the first quarter of the first year the 20% deposit is made on

Table 5-2

MANPOWER REQUIREMENTS

	Number of Man Years	Yearly Expenditure
General Manager	1	$20,000
Secretary and Receptionist	2 @$6000	12,000
Plant Manager	1	12,000
Fermentation Operators	2 @$8,000	16,000
Transport Driver	2 @$8,000	16,000
Dryer and Pelletizer	2 @$8,000	16,000
Maintenance Fitters	3 @$8,000	24,000
Chemist and Lab Technician	1	10,000
General Labor	3 @$5,000	15,000
Scavengers	2 @$6,000	12,000
Cleaners	2	10,000
Animal Husbandry Manager	1	12,000
General Labor for Animals	3	18,000
Grinder Operators	2 @$7,500	15,000
Total Labor Force	27	$196,000

$196,000 + 12%/fringe benefits = $220,000.

TABLE 5-3

CASH FLOW

		First Year				Second Year				Third Year			
	ENGR	1st	2nd	3rd	4th	1st	2nd	3rd	4th	1st	2nd	3rd	4th
EXIM Bank		153,340					108,366		108,366		108,366		108,366
Algae Ponds		11,400	50,000	50,000	3,000								
Solar Heaters		1,700	6,872	6,872	1,716								
Fermentation Tanks		10,500	69,000	69,000	16,500								
Sheep Sheds		10,000	48,500	48,500	10,000								
Plant Building		12,000	50,000	50,000	8,000								
Fees	185,000	85,000	85,000	85,000	85,000								
Land		100,000											
Sheep			60,000	100,000									
TOTAL PLANT & EQUIP.	185,000	383,940	369,372	409,372	124,216		108,366		108,366		108,366		108,366
					OPERATING EXPENSES								
Energy			25,000	53,125	53,125	60,000	60,000	60,000	60,000	63,000	63,000	63,000	63,000
Labor		10,000	30,000	55,000	55,000	60,000	60,000	60,000	60,000	75,600	75,600	75,600	75,600
Tech. Consult.	5,000	12,500	12,500	12,500	12,500	13,500	13,500	13,500	13,500	16,200	16,200	16,200	16,200
Sheep Shearing							10,000				12,000		
Maintenance						10,000	10,000	10,000	10,000	12,000	12,000	12,000	12,000
TOTAL OPERATING EXPENSES	5,000	22,500	67,500	120,625	120,625	143,500	153,500	143,500	143,500	166,800	178,800	166,800	166,800
					REVENUES								
Drop Charges	20,000	30,000	51,100	51,100	51,000	51,100	51,100	51,100	51,100	61,320	61,320	61,320	61,320
CH_4					40,000	75,500	75,500	75,500	75,500	86,825	86,825	86,825	86,825
Wool							150,000				192,349		
Lambs					20,000	43,800	43,800	43,800	43,800	56,940	56,940	56,940	56,940
Algae					25,000	57,724	57,724	57,724	57,724	69,269	69,269	69,264	69,269
Poultry Feed					120,000	200,000	246,375	246,375	246,375	295,650	295,650	295,650	295,650
Paper			20,000	24,000	55,000	65,000	65,243	65,243	65,243	78,292	78,292	78,292	78,292
Glass			5,000	5,000	10,000	11,000	11,046	11,046	11,046	13,255	13,255	13,255	13,255
Ferrous Metal			5,000	10,750	10,750	10,750	10,750	10,750	10,750	12,900	12,900	12,900	12,900
Non-Ferrous Metal			5,000	20,000	24,000	25,000	25,476	25,476	25,476	30,895	30,895	30,895	30,895
TOTAL REVENUE	20,000	30,000	86,100	110,850	359,890	539,874	737,014	587,014	587,014	705,346	897,665	705,346	897,665
TOTAL EXPENSES	190,000	406,440	436,872	529,997	249,841	143,500	261,866	143,500	251,866	166,800	287,166	166,800	287,166
BALANCE	(170,000)	(376,440)	(350,772)	(419,147)	111,009	396,874	475,148	443,514	335,148	538,546	610,499	538,546	418,180
SUMMATION	(170,000)	(546,440)	(897,212)	(1,316,359)	(1,205,350)	(808,913)	(33,829)	109,687	444,835	983,381	1,593,880	2,137,426	2,550,606

the equipment and the equipment is delivered. Contracts are also let for the construction work and construction commences immediately. Construction is scheduled so that by the 2nd quarter the equipment is installed and test runs are made. The first contengent of sheep is delivered. By the end of the third quarter the system is in operation.

See cash flow Table 5-3. The "break-even" point is the 3rd quarter of the first year with a debit of $1,316,359 without depreciation, taxes or insurance.

8. Depreciation:

equipment = $1,064,110 @ 5 years = 212,822 ÷ 4 = $53,205 quarterly

Fixed plant and buildings = $1,058,560 @ 20 years = 52,528 ÷ 4 = 13,132

Sheep = $160,000 @ 5 years = $32,000 ÷ 4 = 8,000

Total = $74,337

See Depreciation Cash Flow, Table 5-4.

9. Sensitivity

In order to determine the system sensitivity to market fluctuations the price of poultry rations was reduced by 50% (from $90 per ton to $45 per ton). The "break-even" point remains in the 4th quarter of the first year, however, the total revenue at the end of the 3rd year is reduced from 2,550,606 to 1,392,048. See Table 5-5 Cash Flow with Poultry Ration Reduced by 50%

Another cash flow was prepared to determine the sensitivity of the system to completion delays in construction. The completion of fermentation tank was delayed one quarter, see table 5-6. (Delays in Fermentation Tank completion.) The "breakeven" point is in the 4th quarter with a total deb t of $1,553,067. This delay increased the deb t by $236,708 where as the fermentation tank only cost $165,000.

TABLE 5-4

CASH FLOW WITH DEPRECIATION

		1st Year				2nd Year				3rd Year			
	ENGR.	1st	2nd	3rd	4th	1st	2nd	3rd	4th	1st	2nd	3rd	4th
TOTAL REVENUES	20,000	30,000	86,100	112,850	355,850	539,874	737,014	587,014	587,014	705,346	897,665	705,346	897,665
Depreciation	---	---	---	74,337	74,337	74,337	74,337	74,337	74,337	74,337	74,337	74,337	74,337
TOTAL EXPENSES	190,000	406,440	436,872	529,997	244,841	143,500	261,866	143,500	251,866	166,800	287,166	166,800	287,166
DEPRECIATION PLUS EXPENSES	190,000	406,440	736,872	604,334	319,178	217,837	336,203	217,837	325,203	241,137	361,503	241,137	361,503
BALANCE	(190,000)	(376,440)	(350,772)	(493,484)	36,672	322,037	400,811	369,177	261,811	464,209	536,162	464,209	536,162
SUMMATION	(170,000)	(346,440)	(897,212)	(1,390,696)	(1,354,024)	(1,031,987)	(631,176)	(261,999)	(188)	464,021	1,000,183	1,464,392	2,000,554

TABLE 5-5

CASH FLOW WITH POULTRY RATION PRICES REDUCED BY 50%

		First Year				Second Year				Third Year			
	ENGR.	1st	2nd	3rd	4th	1st	2nd	3rd	4th	1st	2nd	3rd	4th
TOTAL REVENUES	20,000	30,000	86,100	110,850	295,850	439,874	613,827	463,827	463,827	557,521	649,840	557,521	649,840
TOTAL EXPENSES	190,000	406,440	436,872	529,997	244,841	143,500	261,861	143,500	251,866	166,800	287,166	166,800	287,166
BALANCE	(170,000)	(376,440)	(350,772)	(419,147)	51,019	296,374	341,966	320,327	211,961	380,721	362,684	380,721	362,684
SUMMATION		(546,440)	(897,212)	(1,316,359)	(1,265,340)	(968,966)	(627,000)	(306,673)	(94,712)	286,009	648,693	1,029,414	1,392,098

TABLE 5-6

CASH FLOW WITH DELAY IN FERMENTATION TANK COMPLETION

		1st Year				2nd Year				3rd Year			
	ENGR.	1st	2nd	3rd	4th	1st	2nd	3rd	4th	1st	2nd	3rd	4th
Fermentation Tanks		10,500	30,000	39,000	69,000	16,500							
TOTAL PLANT & EQUIP.	185,000	383,948	330,372	379,372	176,716	16,500	108,366	---	108,366	---	108,366	---	108,366
TOTAL OPERATING EXPENSES	5,000	22,500	67,500	120,625	120,625	143,500	143,500	153,500	143,500	166,800	166,800	178,800	166,800
TOTAL REVENUES	20,000	30,000	---	86,100	110,850	355,858	539,874	737,014	587,014	705,346	705,346	897,665	705,346
TOTAL EXPENSES	(190,000)	(406,448)	(397,872)	(517,997)	(287,556)	(160,000)	(251,866)	(153,500)	(251,866)	(166,800)	(275,166)	(178,800)	(275,166)
BALANCE	(170,000)	(376,448)	(397,872)	(431,897)	(176,850)	195,850	289,948	583,514	335,148	538,546	430,180	718,865	430,180
SUMMATION	(170,000)	(346,448)	(944,320)	(1,376,217)	(1,553,067)	(1,357,217)	(1,067,269)	(481,759)	(146,607)	391,939	822,123	1,540,988	1,971,088

C. Summary of Economic Considerations

The income from the system operations is ummarized in Table 5-7 (Summary of Yearly Income). This income is conservative as can be seen in the schedules Appendix A where each item is discussed separately. Calculations show that with a capital expenditure of $2,382,670 (see page 75) a yearly revenue of $2,466,716 is produced (see Table 5-7, page 83). The yearly operating and maintenance expenses are $472,500 (see energy and maintenance, page 75 and manpower requirements table 5-2 page 76). This leaves an annual net income of $1,994,216 before depreciation, taxes and debt services.

TABLE 5-7

SUMMARY OF YEARLY INCOME

By-Products	Yearly	
CH_4	$306,600	
Wool	167,234	
Lambs	175,200	
Algae Protein	230,862	
Poultry and Stock Feed	926,370	
Paper Sales	273,250	
Glass	43,000	
Ferrous Metals	43,800	
Non-Ferrous Metals	96,000	
SUBTOTAL	$2,262,316	
Drop Charges at $4.00 per ton		
100 ton muncipal waste	$ 146,000	
10 ton swill		
10 Tree pruners		
10 ton wheat waste		
10 ton BUILDERS WASTE and Special Collectors	58,400	
TOTAL 140 tons per day @ $4.00	$ 204,400	$2,466,716

Chapter VI

CONCLUSIONS AND RECOMMENDATIONS

A. General

The proposed system presents solutions to solid waste management problems which may be inplemented with existing technology. Furthermore the proposed system is economically usable, environmentally desirable and socially acceptable.

B. The System is Economically Viable

The output of reclaimed and bio-chemical processed meterials far exceeds the costs of processing the refuse.

C. The System is Socially Acceptable

Reclamation is a part of the present social value system. Feeding "garbage" to animals has been socially acceptable for hundreds of years. The system has the image more akin to intensive farming than to a "garbage dump."

D. The System is Environmentally Desirable

There is no negative environmental impact on the air, land and water. There are no environmental shadows. The system uses the same methods that occur in natural processes. However, the rate of production of wastes by man now far exceeds the rate by which natural ecological chains can handle them. This system only speeds up these natural processes thereby keeping pace with the production of refuse.

E. The System is Compatible with Other Operations

1. Transfer Stations. The system could be "plugged in" to transfer station operations. The refuse could be separated and classified at the station where the inorganics are sold. The organics are then piped (or otherwise transported) to a suitable site for biochemical conversion.

2. Desirable Landfill. The organic fraction of municipal refuse produces the contamination of land and water. When this fraction is

removed for bio-chemical conversion the inorganic fraction can safely be used for landfill.

G. Systems Stability

The system is stable with varying market prices as shown in poultry ration price variations. In order to maintain a physical stability of the system, the number of sheep can be varied thereby adjusting the amount of nitrogen to the anaerobic reactor. Ground wood (builders' waste) may be stored and used when there are inputs with a high nitrogen content.

H. Alternative Action

Other systems available are:

1. Continue present which has a short economic, environment
2. Shred, compress and landfill; this increases the costs. However it increases the life span of existing landfill sites with increasing pollution to the land.
3. Incineration; this is unlikely due to costs and air pollution problems.
4. Pyrolysis and composting; this is a more plaus ble alternative since there is material recovery and at the same time it produces a minimum of pollution.

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APPENDICES

APPENDIX A

Schedule 1

THREE YEAR MARKET SURVEY

Schedule Number	Description	Source	1972	1973	1974	Average	Assumed
2	Methane Gas	State Dept. Fuel & Energy	Allow $2.00 per 28.32 cubic meters (1,000 cubic feet)				$ 2.00
3	Wool	Agriculture Dept.	.94	2.27	1.80	1.67	1.67
4	Lamb	Agriculture Dept.	5.90	7.50	8.40	7.30	7.30
5	Algae Protein	Wesfeeds Pty. Ltd.	140.00	210.00	230.00	194.00	230.00
6	Poultry Feed	Wesfeeds Pty. Ltd.	46.00	70.00	90.00	69.00	90.00
7	Paper	Japanese Market	60.00	120.00	142.00	107.00	57.00
		Aust. Paper Manf.	11.80	11.80	13.90	12.50	
		American Market	20.00	55.00	60.70	48.30	
8	Glass Cullet	Aust. Glass Co.	6.41	6.41	10.00	7.60	12.00
9	Steel Cans-Ferrous Metals	Milne Metals	15.00	12.00	25.00	17.50	12.00
10	Nonferrous Metals-						
	Average	Milne Metals	483.00	430.00	511.00	474.00	254.00
	Copper	Milne Metals	896.00	784.00	1008.00	896.00	
	Brass	Milne Metals	500.00	490.00	500.00	497.00	
	Aluminum	Milne Metals	268.00	224.00	268.00	254.00	

A

Schedule 2

Methane Gas (CH_4)

General (Source: Department of Fuel and Energy)

The Minister for Fuel and Energy, Mr. Mensaros, warned on the 14th of November, 1974, in the local press that a national gas shortage could be critical. The threat is important because of the grave doubts about when the North West shelf gas reserves will be brought into production. If supplies were unlimited the natural gas consumption by Perth and surrounding areas could almost double overnight. According to the Department of Fuel and Energy the domestic consumption of natural gas per day equals 15,000,000 ft^3. A waste recycling plant capable of processing 140 tons will produce approximately 420,000 ft^3 CH_4 per day and several plants processing 90% of the metropolitan population's waste would thus produce approximately 15 times as much (6,300,000 ft^3) or nearly 43% of domestic consumption. Consequently, if plants such as proposed here were commissioned they could go a long way to extending the life of the Dongara natural gas. Severe limits on the amount of gas available from the Dongara field -- the only natural gas source at present in production in Western Australia -- have already caused restrictions in the sales of the gas in Perth and the southwest. The State Electricity Commission is now cutting back its consumption of natural gas so that it will have more available for the critical years 1977-1980. Mr. Mensaros said that in this way it was hoped that supplies for domestic consumption could be maintained until 1980.

However, it appears highly unlikely that gas from the North West shelf can be delivered to Perth before 1981.

Quantity

Through the process of anaerobic digestion, the organic fraction of municipal refuse produces 420,000 ft^3 of methane.[36] This compares favorably with tests conducted over the past several years by the U.S.D.A. in Peoria, Illinois,[37] with a loading of 7.5 percent solids and a detention time of ten days. A mass reduction of 65% was recorded. Gas production was 8.75 ft^3 per pound of volatile solids. Therefore, 99,843 pounds at 92% volatile solids would produce 803,740 ft^3 of gas. This was recorded as 52% CH_4 or 417,944 ft^3 of CH_4.

Income

Therefore, the income derived from the sales of CH_4 would equal:

	Total Income	% Increase
Year 1	Construction Phase	--
Year 2	$302,667	--
Year 3	$348,067	15
Year 4	$400,277	15

Future Markets

The allowance for the increase in the price of natural gas in future years is kept to approximately 15% (inflation allowance).

Schedule 3

WOOL

General (Source: Department of Agriculture - Western Australia)

Recent tests in Australia and the United States have proven that the quantity and the quality of wool production is vastly improved under controlled conditions. Therefore, an intensive scheme such as is proposed here will produce a wool with a ready market at premium prices.

From government agricultural statistics, the annual average production of wool from sheep is 4.5 kilos, and from lambs 1.36 kilos.

Cost (refer to Schedule 1)

Even though the fleece quality is expected to be of a first class quality, the prices quoted on the three year survey were based on average quality grade merino fleece. The price used will be $1.67 per kilo of wool, being the average wool price for this average quality grade over the last three years. (It would be expected that high quality wool would demand a price above the average and that production from controlled conditions would exceed the average.)

Income

Based on the average price from the three year survey, income from:

a) 15,000 sheep x 4.5 x 1.67 =	$ 112,725
b) 24,000 lambs x 1.36 x 1.67 =	54,509
	$ 167,234 per annum

Therefore the income anticipated from the sale of wool would equal:

	Total Income	% Increase
Year 1	Construction Phase	--
Year 2	$150,000	29
Year 3	$192,349	15

Future Market

Cheap synthetic fibres are largely responsible for reducing the demand and thus the price for wool. Even though the demand for wool is presently low, it is anticipated that it will rally due to increases in the prices of synthetics. Synthetic yarns are derived from petro chemicals. Thus the average annual increase is anticipated to be approximately fifteen percent.

Schedule 4

LAMB

General (Source: Department of Agriculture - Western Australia)

It is well established that the lambing rate plus the carcass quality is vastly improved under the controlled conditions of an intensive scheme such as is proposed here.[28] The sucker lamb will be weaned at 12 to 14 weeks of age and sold directly to a wholesaler. Calculations will be based on a lambing rate of 1.60.[29] Several large wholesale dealers, including Patton Export Pty. Ltd. and Tip Top Meats Pty. Ltd., have tentatively committed themselves to the purchasing of the entire production of lambs.

Cost (Refer to Schedule 1)

The wholesale price for sucker lamb has fluctuated tremendously over the last five years, so for the basis of this study the price will be averaged over the past three years. Thus, it is reasonable to anticipate a price of at least $7.30 per lamb.

Income

Lambs per annum = 24,000 at $7.30 = $175,000

Therefore, the income anticipated from the sales of lambs would equal:

	Total Income	% Increase
Year 1	Construction Phase	--
Year 2	$ 122,640	--
Year 3	$ 175,200	30
Year 4	$ 192,720	10

Future Market

The percentage increase per annum has been kept to a nominal ten percent. The large percentage increase between year two and year three is caused by below capacity production in year two.

Schedule 5

ALGAE PROTEIN CONCENTRATE

General (Source: Literature Research)

The University of California has cultivated algae protein grown on the supernatant from an anaerobic digestor and successfully fed it to animals since 1960.[41] This protein concentrate is considered the equivalent to soya bean protein. Some algae are equivalent to fish meal protein. The local market for this protein concentrate is well in excess of anticipated production and at present these supplies are imported. Therefore, a locally produced product with a constant price structure and supply would be readily absorbed by local demand. The maximum algae production, based on the availability of nitrogen, is 3.056 tons per day (dry weight). Allowing for biological efficiency of 90% in harvesting, the possible production would equal approximately 2.75 tons per day.

Cost (Refer to Schedule 1)

The prices stated in Schedule 1 are for soya bean protein meal, but as the lysine level of overseas samples of algae protein is considerably higher, it is anticipated that once final analyses are carried out to prove this, higher prices could be expected.

The local firm of Wesfeeds Pty. Ltd. have tentatively committed themselves to purchasing the entire production at market prices. Due to the rapid escalation of prices over the last three years, and its expected higher qualities, it was decided to use the current market price instead of the three year average, i.e. $230 per ton.

Income

Therefore, the income anticipated from the sale of algae protein concentrate will equal:

	Total Income	% Increase
Year 1	Construction Phase	--
Year 2	$ 115,448	--
Year 3	$ 230,896	50
Year 4	$ 277,075	20

Future Market

The supply of protein concentrates and fertilizers fluctuates dramatically from year to year and this is expected to get more severe in the near future. Due to these fluctuations and the general overall shortage, it is anticipated that the annual increase in income for algae production would be approximately 20%.

Schedule 6

POULTRY FEED

General (Source: Laboratory Tests)

The only product of some doubt is poultry feed. This is composed of sludge from the reactor combined with wheat dust and putrescibles from the hydro pulper. This product has not yet been approved by the Department of Agriculture of Western Australia for feeding poultry. However, tests conducted for the United States Department of Agriculture[38] have given favorable results for digestibility and protein content of the single cell protein fraction that is a by-product from the anaerobic digestor. The single cell protein (S.C.P.) together with other carboydrates and products, combines favorably to produce a stock feed ideally suitable for poultry (layers and broilers).[3] The feed would have a protein content of 15.25% with all the essential amino acids and necessary carbohydrates.[36-37]

Based on these calculations the expected production will be 28.2 tons (dry weight) of pelletized feed per day. The local firm of Wesfeeds Pty. Ltd. has already tentatively committed itself to purchase the entire production at market prices.

Cost (Refer to Schedule 1)

As can be seen from the three year market survey in Schedule 1, the average price per ton equals $69.00. But, as the prices also reflect a constant rapid increase over the past three years and market expectations are that it will continue to do so, the price used for the basis of this feasibility is $90.00 per ton, which is the current market price.

Income

Therefore, the anticipated income from the sale of poultry feed would equal:

Poultry Feed	Total Income	% Increase
Year 1	$ 120,000 (Construction Phase)	---
Year 2	$ 984,000	---
Year 3	$ 985,500	---

Future Market

Due to the anticipated continuation of world food shortages, the increase in the price of stock feeds could be expected to exceed the inflation rate, however, no increase is calculated here.

Schedule 7

WASTE PAPER

General (Source: Japanese Department of Commerce)

Shortages of virgin wood fiber have produced a demand for recycled paper throughout the world which has increased dramatically in the last five years. In the U.S.A. the wholesale price index for waste paper more than doubled in 1973. In the United States in mid 1974, prices had reached $55.00 per ton, while Japanese prices had reached $120.00 per ton plus a $22.00 importer's subsidy. Based on these calculations, the anticipated production of paper (dry weight) that would be suitable for recycling would be 35%, or approximately 13 tons.

Cost (Refer to Schedule 1)

As can be seen from Schedule 1, the highest price that can be expected from the local market would be $13.80 per ton. As we are producing large enough quantities to warrant shipping to export markets, the feasibility study will be based on a price of $57.20 per ton. This is currently being negotiated with Japanese markets.

Income

Therefore, the anticipated income from the sales of paper would equal:

	Total Income	% Increase
Year 1	$99,000 Construction Phase	---
Year 2	$200,000	15%
Year 3	$231,168	15%

Future Market

It is expected that the supply of virgin wood fibre will be well behind demand in the near future and the demand for recycled waste paper should increase still further.

Schedule 8

GLASS

General

Prices of glass cullet referred to in the schedule allow for its transport. Even though the aggregate price for mixed cullit is $7.6 per ton, Australian Glass Manufacturers Company have tentatively committed themselves to purchasing the sorted production at the present rate of $12. per ton. As no reversal of market prices is expected, the market price of $12.00 per ton has been used in this feasibility study.

Cost

(Refer to Schedule 1)

Income

Therefore, the anticipated income derived from the sales of glass cullit would equal:

	Total Income	% Increase
Year 1	Construction Phase	--
Year 2	44,000	15
Year 3	53,000	15

Future Market

The materials that are used in the production of glass are becoming more scarce, and consequently the percentage of cullet used in the process is increasing. Thus, the demand will increase. Due to environmental considerations, there is expected to be a return to reusable containers made of glass, thus placing a heavy demand on the need for recycling cullet.

Schedule 9

FERROUS METALS

<u>General</u>

Of the total municipal solid waste 11.78% is ferrous metals; approximately 10 tons of this is recovered. As the price and demand for unprocessed steel cans varies greatly from year to year, it was decided to use the price of $12.00 per ton.

Calculations show an anticipated production of 10.00 tons per day of ferrous metals.

<u>Cost</u> (Refer to Schedule 1)

a. Ferrous Metals

This price of scrap iron fluctuates from year to year, sometimes quite drastically, so the price used will be based on $12.00.

<u>Income</u>

A local firm, Milne Metals Pty. Ltd., has tentatively committed themselves to the purchasing of the entire production at market prices.

Ferrous Metals	Total Income	% Increase
Year 1	20,900 Construction Phase	---
Year 2	43,800	17
Year 3	51,600	17

Schedule 10

NON FERROUS METALS

General

Of the total municipal waste, 1.2 tons is non-ferrous metal. The majority of this consists primarily of copper, brass, and aluminum. Of these fractions aluminum makes up the largest portion. These metals are readily separated from the municipal waste and from each other by known technology. The total production of non-ferrous metal recovered = 1.1 tons per day.

Cost (Refer to Schedule 1)

The price for non-ferrous metals was based on the price of aluminum at $254 per ton.

Income

Therefore, the anticipated income from the sales of non-ferrous metals would equal:

	Total Income	% Increase
Year 1	$ 49,000	Construction Phase
Year 2	$101,904	12
Year 3	$123,000	12

Future Market

Even though the prices for non-ferrous metals fluctuate from year to year due to overall shortages and increases in the cost of production, the anticipated annual increase in income from non-ferrous metals would equal approximately 12-20%.

Schedule 11

DROP CHARGES - MUNICIPAL WASTE, SWILL AND DUST

General

This processing system will accept all municipal waste (from the local government or the public) and swill. Also, certain industrial wastes which are compatible with the process will be accepted; that is, carbohydrates and cellulose materials such as wheat dust, tree prunings and builders', waste.

Quantity

The initial quantities to be anticipated, based on the shine population, will be 100 tons per day plus 10 tons per day of swill, 10 tons per day of wheat dust, and 20 tons per day of tree prunings and builders' waste. It is anticipated that the actual volume of waste will increase annually, due to the relevant increases in population and the percentage of packaging due to the continuation of the "throw away society" attitudes. Even so, this feasibility has allowed for a constant price and only an inflationary increase in drop charges will be allowed.

Cost

The drop charge for the shires is to be established so that it is compatible with their present cost structure for the operation of their landfill tips. In most cases, this represents approximately \$ 3.50 - \$5.00 per ton, and in this case we have used \$4.00 per ton. (This price is still to be finalized with the shires.) This drop charge will also be used for the general public, the swill and the wheat dust.

Income

Therefore, the income derived from fees for drop charges from the shires and other sources would equal:

	Total Income	% Increase
Year 1	$ 152,200	--
Year 2	$ 204,400	20
Year 3	$ 245,200	20

Future Markets

Long-term contracts will be entered into with the shires based on drop charges that will be fixed to inflation.

APPENDIX B

TERMS AS DEFINED BY THE AMERICAN PUBLIC WORKS ASSOCIATION

1. Waste

The word waste refers to the useless, unwanted, or discarded materials resulting from normal community activities. Wastes include solids, liquids, and gases. Atmospheric wastes consist of particulate matter such as dust and smoke, fumes, and gases. Liquid wastes consist mainly of sewage and industrial wastewaters, including both dissolved and suspended matter. Solid wastes are classed as refuse. The physical state of wastes may change in their conveyance or treatment. Dewatered sludge from wastewater treatment plants may become solid wastes; garbage may be ground and discharged into sewers becoming water-borne wastes; and fly ash may be removed from stack discharges and disposed of as solid or as water-borne wastes...

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2. <u>Refuse</u>

Refuse comprises all of the solid wastes of the community. It also includes semi-liquid or wet wastes with insufficient moisture and other liquid contents to be free-flowing.

The component materials of refuse can be classified in several different ways. In connection with some problems, its point of origin is important. From this standpoint, it can be considered made up of domestic, institutional, commercial, industrial, agricultural, or street refuse. In other cases, the point of origin is not as important as the nature of the material itself, and classification may be made on the basis of organic or inorganic character, putrescibility or non-putrescibility, combustibility or noncombustibility. One of the most useful classificaiions is based on the character of the materials and this includes garbage, rubbish, ashes, bulky wastes, street refuse, dead animals, abandoned vehicles, construction and demolition wastes, industrial refuse, agricultural wastes and special wastes. Table 1-1 represents such a grouping of refuse materials, describes each category, and indicates in a general way its origin.

Most of the duties of the refuse collection agency consist of the collection of garbage, rubbish, and ashes either separately or together. When combined collection of garbage and rubbish is practiced, the term "refuse" should be used whether or not ashes and yard wastes are included. Because of the ill-defined nature of the term "trash," it is recommended that the term "rubbish" be used instead in cases where the storage and collection of garbage is separated.

Bulky wastes may require collection from residential and commercial areas or from public property and vacant lots. They are given separate classification because often special collection vehicles and trips are required for their collection.

Street refuse is generally collected as a part of the street maintenance and cleaning functions. While removal and disposal of dead animals may be included in the duties of the refuse collection agency, it is generally managed as a special problem rather than as a routine activity. Responsibility for removal of abandoned vehicles may rest with the street cleaning agency or the police department. Construction and demolition wastes may be the responsibility of the contractor, private collector, or the refuse collection agency, but requirements for their disposal should be established by the municipality or other administrative agency.

Ordinarily, industrial solid wastes are the responsibility of the industry, but there is a trend towards city collection of some types of "trade" refuse. Wihh expanding metropolitan areas, agricultural activities are often engulfed by residential or commercial development. Where disposal of manures or crop residues can no longer be done on the farm without public health or nuisance hazards, these wastes require consideration in the overall refuse collection and disposal plan. There is a trend towards more culling, cleaning, and even packing of fruits and vegetables in the fields, leaving wastes which may putrefy causing fly and odor problems, unless they are suitably removed or treated.

3. Garbage

Garbage is the animal and vegetable waste resulting from the handling, preparation, cooking, and serving of foods. It is composed largely of putrescible organic matter, and its natural moisture content. The term garbage does not include food-processing wastes from canneries, slaughterhouses, packing plants, or similar industries; large quantities of condemned food products; or oyster or clam shells. Garbage originates primarily in home kitchens, stores, markets, restaurants, hotels, and other places where food is stored, prepared, or served.

Garbage decomposes rapidly, particularly in warm weather, and may soon produce disagreeable odors. When carelessly stored, it is a source of food for rats and other vermin and serves as a breeding place for flies.

4. Swill

The terms "swill," "slops," and "offal," which are frequently found in city ordinances to define garbage, are not properly synonymous with garbage. "Swill" and "slops" connote semi-liquid waste material consisting of garbage and free liquids, collected from restaurants, hotels, and institutions. The word "offal" has had so many different meanings that its use is avoided except to refer to intestines and discarded parts from the slaughter of animals.

5. Market Refuse

Market refuse comes from wholesale and retail stores and markets as a result of the handling, storage, and selling of foods. It originates principally in poultry, fish, meat, vegetable, and fruit markets, and includes large quantities of putrescible garbage along with some rubbish such as wooden crates and cardboard boxes. It also includes some condemned foods but not large quantities of spoiled material.

6. Rubbish

Rubbish consists of a variety of both combustible and noncombustible solid waste materials from households, stores, and institutions. This waste is defined more specifically as "combustible rubbish" and "noncombustible rubbish," but whenever the term "rubbish" is used alone it means a combination of combustible and noncombustible rubbish. When other materials such as garbage or ashes are collected with rubbish, the mixture should then be designated as "combined" refuse.

Combustible Rubbish. Combustible rubbish consists of miscellaneous burnable materials. In general, it is the organic component of rubbish such as paper, rags, cartons, boxes, wood, excelsior, bedding, rubber, leather, grass, leaves, yard trimmings, plus combustible inorganic materials such as plastics. Combustible rubbish, primarily organic, is generally not highly putrescible and therefore may be properly stored for relatively long periods without being a nuisance. It has a high heat value and when dry, burns freely without forced draft or auxiliary fuel. While garbage is also largely organic and combustible, it is generally classified separately from combustible rubbish because of its putrescibility and high moisture content.

Yard rubbish consists of prunings, grass clippings, weeds, leaves, and general yard and garden wastes. When collected, it often contains some earth clinging to the roots of grass, weeds, and discarded plants. Much of the yard rubbish is green vegetation which, when kept moist or stored in large masses, decomposes rather rapidly. While not ordinarily objectionable, these materials may serve as a breeding place for insects. This green material can be burned in an incinerator, but normally will not sustain a fire alone. Dried vegetation, dead leaves, and plants do not cause any sanitary or nuisance hazard and will burn readily in an open fire.

Yard rubbish is really a part of combustible rubbish, rather than a main class by itself. However, cities frequently make different arrangements for its collection, or even exclude it entirely from their collection service. Yard rubbish may be collected with other rubbish, but cities often specify different types of containers or bundles of certain maximum size for its storage on the premises.

Noncombustible Rubbish. Noncombustible rubbish consists of miscellaneous refuse materials that are unburnable at ordinary incinerator operating temperatures (1300° F to 2000° F). For the most part, it is the inorganic component of rubbish, such as tin cans, metals, dirt, ceramics, glass, and the like. Although noncombustible rubbish is very stable, it is esthetically objectionable and may harbor rodents and other vermin if it is carelessly stored.

Tin cans and bottles that once contained food may have a residue of putrescible material clinging to them when discarded. Under ordindary conditions, this organic matter desiccates rather than putrefies. In a warm, moist atmosphere, however, the remnants of food in noncombustible containers may serve as breeding places for flies and other insects and may necessitate more frequent collection than normally required for noncombustible rubbish.

7. Ashes

Ashes are the residue from the burning of wood, coal, coke, and other combustible material in homes, stores, institutions, and small industrial establishments for the purposes of heating, cooking, and disposing of waste combustible material. Cinders that are produced in large quantities at steam-gathering plants are not included within the meaning of the term.

Ashes are usually composed of a mixture of fine powdery residue, cinders, clinkers, and small portions of unburned or partially burned fuel or other material. Some metal, glass, and combustible materials are usually found in ashes when they are presented for collection. Since the mixture is mostly inorganic, it is valuable for making fills on low land, or as cover material in sanitary landfills. Except for the dust that they may create, ashes are not objectionable from a nuisance or esthetic standpoint.

The residue from central or municipal incinerators should be classified under industrial refuse, rather than under ashes. Incinerator residue may be quite substantial in amount and generally contains most of the items listed under noncombustible rubbish (see Table 1-1).

8. Bulky Wastes

Bulky wastes are large items of refuse such as appliances, furniture, large auto parts, trees and branches, palm fronds, stumps, flotage, etc. These may be generated in residential or commercial areas, on public property such as parks, streets, alleys, and beaches, or they may be abandoned on vacant lots. Some bulky wastes may require special collection arrangements and vehicles.

9. Street Refuse

Street refuse is material picked up by manual and mechanical sweepers, litter from public litter receptacles, and dirt removed from catch basins. It includes dirt, leaves, paper, and the like. Some cities assign the task of collection of street refuse to the regular refuse collection agency, while others assign it to the street department.

10. <u>Dead Animals</u>

As a class of urban refuse, dead animals are those that die naturally or from disease or are accidentally killed. Condemned animals or parts of animals from slaughterhouses or similar places are not included in this term, but are regarded as industrial refuse.

Dead animals may be classified according to size. The large animals are horses, cows, goats, sheep, hogs, and the like. These have value because of the grease and tankage that can be produced from them in rendering plants. Their hides also have some value. Collection of large animals is usually a separate operation and may require special equipment. Small animals include dogs, cats, rabbits, rats, chickens, etc. These can be effectively handled in the routine collection service.

Dead animals are particularly offensive from both sanitary and esthetic viewpoints and usually must be collected promptly -- often on an emergency call basis. They putrefy rapidly, particularly in warm, moist atmospheres, and have a strong attraction for flies and other vermin. Animal traffic victims are sometimes crushed by many vehicles passing over them and therefore must be picked up promptly.

11. <u>Abandoned Vehicles</u>

This class of refuse includes passenger automobiles, trucks, and trailers that are no longer useful as such and have been left on city streets and in other public places. Usually they are found stripped of tires, wheels, lights, and other easily salvaged parts.

12. <u>Construction and Demolition Wastes</u>

Construction and demolition wastes are the waste building materials and rubble resulting from construction, remodeling, repair, and demolition operations on houses, commercial buildings, pavements, and other structures. They comprise a great variety of rejected matter, such as excavated earth, stones, concrete, bricks, plaster, roofing, sheathing, lumber, insulation, and wastes from installation or demolition of plumbing, heating and electrical systems.

Small amounts of this refuse material may be accepted as normal waste from households and stores, but the larger, bulkier amounts require special collection either by private industry or by the municipality.

13. <u>Industrial Refuse</u>

Industrial refuse consists of the solid waste materials from factories, processing plants, and other manufacturing enterprises. It is usually of a special character, peculiar to a specific industry, and its removal should be the responsibility of that industry. Refuse of this class may include putrescible garbage from food-processing plants and slaughterhouses; condemned foods; cinders and ashes from power plants, central incinerators, and large factories; and miscellaneous manufacturing wastes. Because putrescible industrial refuse may cause serious nuisances and even endanger public health, its storage, hauling, and disposition should be subject to municipal control.

Industrial refuse should not be confused with commercial refuse or so-called "trade wastes" which emanate from stores, hotels, restaurants, markets, and similar concerns operated for profit.

14. Special Wastes

Special wastes are defined as hazardous wastes by reason of their pathological, explosive, radioactive, or toxic nature. They require careful handling and disposal to render them innocuous or safe from human and animal contact for an adequate decay period. While most of these wastes will be disposed of by the institution or industry generating them, others from residential or commercial areas may be put out for regular municipal collection. These are mainly solid wastes or liquids in containers, generally explosive or highly flammable in nature, which should be carefully segregated at the source or at the time of pickup. They present hazards to collectors and may cause dangerous explosions or flash fires at incinerators, grinding plants, sanitary landfills, or refuse dumps.

15. Animal and Agricultural Wastes

Agricultural wastes are principally the manures and crop residues from various agricultural pursuits including dairying and the raising of livestock and poultry. Although agriculture is normally thought of as separated from municipalities, in many areas the rapid growth of cities and suburbs has engulfed various types of agriculture. In some cases, residential, commercial, or industrial developments spring up on one or more sides of a farm and the usual farm methods of storage and disposal of wastes are impractical or create nuisance and health hazards.

Animal wastes include, in addition to those mentioned above, wastes from stables, kennels, pet pens, poultry raising, veterinary establishments, and the like. These wastes are often public health and nuisance problems. Agricultural wastes are largely organic and readily decomposable so that they must be disposed of in a sanitary manner or converted to safe useful products. Although large quantities of agricultural wastes may not be collected along with municipal refuse, their joint treatment or disposal may be most satisfactory and economical.

16. Sewage Treatment Residues

These wastes consist of coarse screenings, grit, and dewatered or air-dried sludge from sewage treatment plants, and pumpings of cesspool or septic tank sludges. While the latter sludges are actually liquid wastes and may be disposed of by approval in certain sewers or at sewage treatment plants, this is often impractical or unacceptable, requiring another method of disposal.

17. Problem Wastes

Problem wastes include bulky wastes, dead animals, abandoned vehicles, construction and demolition wastes, industrial refuse, tree debris, and evictions (debris of no value). Some of these wastes are generally collected or disposed of by those creating them, particularly industrial refuse, and construction and demolition wastes. However, many of these wastes simply accumulate in unauthorized dumping areas or litter our streets, highways, and byways. They are extremely unsightly and may cause very serious health, fire, safety, or nuisance hazards.

APPENDIX C

COMPUTER PROGRAM FOR IN VITRO TESTS

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C:FOCAL-11,PRELIM

 1.10 A "DATE IS "A,B,C,!!
 1.20 T "INVITRO RESULTS      FOCAL  8/1974",!
 1.30 A !,"HOW MANY BATCHES "D,!
 1.50 F G=1,D;D 2
 1.60 A !!,"HIGH STD "U," LOW STD "V
 1.65 F G=1,D;D 3
 1.70 F G=1,D;D 4
 1.80 Q

 2.10 T !!,"BATCH ",%2 G;A "   AVERAGE BLANK "K(G)
 2.15 S Y(G)=0;S J=0;T !!,"HIGH STDS  BATCH "G,!
 2.20 S J=J+1;A !,A1,A2,A3
 2.25 I (A2) 1.1,2.6,2.3
 2.30 S X=[A2-A3+K(G)]*100/[A2-A1]
 2.40 T #,"                         ",%4.02 X
 2.45 S Y(G)=X+Y(G)
 2.50 G 2.2
 2.60 S H(G)=Y(G)/(J-1)
 2.63 T !,"HIGH STD U/C =",%3.01 H(G),"%"!
 2.65 S Y(G)=0;S J=0;T %1 !!," LOW STDS  BATCH "G,!
 2.67 D 2.2
 2.70 I (A2) 1.1,2.85,2.75
 2.75 D 2.3
 2.76 D 2.4
 2.77 D 2.45
 2.80 G 2.67
 2.85 S L(G)=Y(G)/(J-1)
 2.90 T !," LOW STD U/C =",%3.01 L(G),"%"!

 3.01 S M(G)=[U-V]/[H(G)-L(G)]
 3.02 S B(G)=V-M(G)*L(G)
 3.03 T !!,%1 "M("G,"  )  ",%6.04 M(G),%1 "  B("G,"  )  ",%6.04 B(G)

 4.05 T !!!,"BATCH ",%2 G
 4.10 S Z=0;D 5

 5.05 T !,"                    UNCORRECTED            CORRECTED",!
 5.07 A !,"SAMPLE NUMBER "OI;T %7 OI,!!
 5.08 S Z=0
 5.10 S Z=Z+1
 5.20 A A1,A2,A3;I (A2) 5.9,5.9,5.3
 5.30 I (A2-A1) 5.2,5.2,5.4
 5.40 D 2.3
 5.45 S Y=M(G)*X+B(G);T #,"                         ",%3.01 X
 5.50 T "   "Y,!
 5.60 I (19-Z) 5.05,5.1,5.1
 5.90 R
*
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